WORKING PAPER 35

Lite: A Model for Estimating Light Interception and Transmission Through Forest Canopies

Users Manual and Program Documentation

1998

BRITISH COLUMBIA

Ministry of Forests
Research Program

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TABLE OF CONTENTS

ABSTRACT v

1 INTRODUCTION 1

2 APPEARANCE AND STRUCTURE OF THE LITE PROGRAM 3

2.1 Application Frame Display and Main Menu 3
2.2 Multiple Document Interface 4

3 OPENING PANEL 5

3.1 Main Menu 5
3.1.1 File Menu 5
3.1.2 View Menu 14
3.1.3 Help Menu 14

4 CROWN GENERATION USING LAI 2000 PCA INTERPRETATION 17

4.1 File Formats 17
4.1.1 Input Files 17
4.1.2 Input/Output Files 18
4.2 LA Main Menu 18
4.2.1 File Menu 19
4.2.2 View Menu 31
4.2.3 Window Menu 35
4.2.4 Help Menu 37
4.3 Calculations and Algorithms 38
4.3.1 Plot Extents 38
4.3.2 Canopy Cube and Angular View Intersection 38
4.3.3 Leaf Area Determination 38
4.3.4 Leaf Area Index 40

5 TREE STAND AND LIGHT MODELLING 41

5.1 File Formats 41
5.1.1 Input Files 41
5.1.2 Input/Output Files 42
5.1.3 Output Files 43
5.2 Tree Stand Modelling Main Menu 44
5.2.1 File Menu 44
5.2.2 Atmosphere Menu 57
5.2.3 Crown Menu 62
5.2.4 Stems Menu 65
5.2.5 View Menu 70
5.2.6 Window Menu 74
5.2.7 Help Menu 79

5.3 Below Canopy Photographs 80
5.3.1 File Menu 80
5.3.2 View Menu 81
5.4 Calculations and Algorithms 82
5.4.1 Radiation 82
5.4.2 Calculation of Exported Values 85
5.4.3 Crown Generation 87
APPENDICES 91
Appendix A - Open Sky PPFD File (*.pfd) 91
Appendix B - Stem List File (*.stm) 92
Appendix C - Observation Point Map File (*.map) 93
Appendix D - Sky Brightness Chart 94
Appendix E - Above Canopy Readings 95
Appendix F - Below Canopy Readings 96
Appendix G - LAI 2000 Light Observations (*.dat) 97
REFERENCES 99

ABSTRACT

LITE is a software package developed to provide both instantaneous (hourly average) and seasonal estimates of photosynthetic photon flux density beneath tree canopies. The model provides utilities for estimating the leaf area contained in each cubic metre of canopy space from either a grid of directional LAI-2000 Plant Canopy Analyzer (PCA) measurements or from tree list data (including stem location, lean, height, height to crown base, crown extent, diameter at breast height, leaf area (if available)). Directional PCA measurements are taken using view restrictors supplied with the instrument (a common approach is to take a reading in each of 4 cardinal directions using a 90° view restrictor). When using PCA data, the user provides information on the location of each grid point (x and y coordinates) and the height to the top and the base of the canopy.

The model calculates the location of the sun, partitions open sky total PPFD into diffuse and direct components, and estimates the penetration of each through the canopy to the selected point of interest. Direct PPFD is assumed to come from the location of the sun, diffuse PPFD is assumed to be evenly distributed across 480 segments of the sky.

The software provides maps of LAI and PPFD across the study site and provides information on the light regime at selected locations. Routines for entering, merging, and editing data are also provided. The model is written for use with MS-Windows™.

1 INTRODUCTION

The density and arrangement of overtopping trees influences the amount of light reaching trees in the understory. On productive mixedwood sites, light reduction by overtopping broadleaves is the primary way in which broadleaves influence the performance of understory conifers. Successful design of mixedwood management regimes requires an understanding of the effects of broadleaf density and arrangement on understory light and on growth of understory conifers. In addition, information on responses of both the conifer and broadleaf components of mixed stands to silvicultural treatments is required. Although instrumentation exists for making measurements of light conditions, the cost and time involved in obtaining the large number of long-term measurements, required to characterize understory conditions, is substantial. Consequently, there is a need for indirect methods for estimating daily, seasonal, and annual light regimes using various indexes or models. Spatially explicit models of key resources driving mixedwood stand dynamics have potential value in generalizing the results from field and greenhouse experiments and other studies.

Understory light (PPFD) is inversely related to basal area of birch or red alder (Comeau 1996). Consequently, growth of understory conifers would be expected to decline as either density or size of the deciduous overstory trees increase. The location of gaps in the broadleaf canopy relative to the conifer can also influence light conditions and growth of conifers.

A variety of attempts have been made to develop simple indexes of light reduction (eg. Messier and Puttonen 1995; DeLong 1991). However, these simple indexes provide information that is only applicable to a certain time, and most often under continuous canopies. Information on how light conditions vary seasonally and annual integrations of light conditions may more effectively describe observed variations in understory tree performance. In addition, more sensitive methods are required to characterize light regimes within and around canopy gaps or, alternatively, within and around patches of broadleaves.

Calculating the amount of light underneath plant canopies requires information on the amount and distribution of leaves in the canopy and the amount of diffuse and direct sunlight reaching the canopy from each portion of the sky. Hutchison and Matt (1977) present an interesting summary of how understory light regimes change seasonally with changes in the amount of solar radiation and the development of the stand leaf area index.

Grace et al. (1987) describe a process model for predicting light interception by coniferous canopies which was an adaptation of earlier models by Norman and Welles (1983). Pukkala et al. (1993) describe a similar model for estimating light levels beneath canopies of Scots pine stands. These models use stand map information together with simple models of crown architecture of individual trees to estimate the distribution of leaf area in tree canopies. They provide an excellent foundation for the construction of a Windows compatible model that is capable of using LAI-2000 and stand

map data as input for estimating understory light conditions.

Detailed measurements of crown architecture, particularly of the distribution of leaf area, are required as a basis for calculating light penetration. In forest stands this generally involves detailed mapping of stem and crown locations, as well as measurement of crown length. Leaf density within crowns is generally estimated using published or locally developed regression estimators, that calculate leaf area as a function of dbh, height or other parameters. The LI-COR LAI-2000 plant canopy analyzer (LI-COR Inc., Lincoln, Nebraska) has potential use for estimating the fraction of light penetrating broadleaf canopies and for estimating the amount of leaf area in canopies (Gower and Norman 1991). The LAI-2000 sensor estimates leaf area within each of 5 angular segments of the sky. Using view restrictors it is possible to restrict the portion of the sky that the sensor views. By collecting LAI-2000 readings from numerous points in a stand, either at known locations or on a systematic grid, it is possible to map the spatial distribution of leaf area in the tree canopy. LAI-2000 measurements can be obtained rapidly, and may eliminate or reduce the need for development of local regression estimators for tree leaf area, and may reduce the need for other measurements.

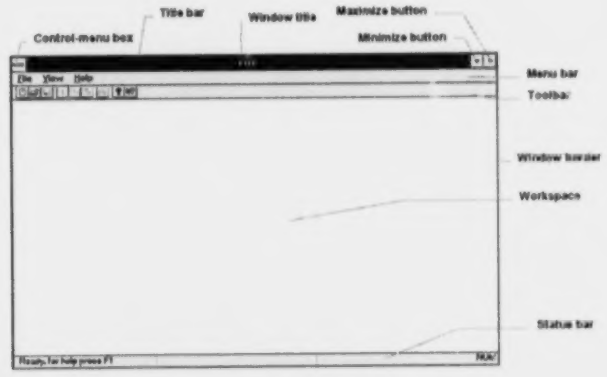
Canham et al. (1988, 1994) describe a Global Light Index (GLI) which is potentially useful for characterizing growing season light conditions in and around gaps. GLI values represent the fraction of full sky light that reaches the measurement point over the entire growing season. GLI is estimated from fisheye photographs taken underneath the tree canopy.

This report describes the design and use of the model LITE which was developed as a tool for estimating light penetration through tree canopies. LITE was written for use with MS-Windows™ 3.1 or higher and requires either LAI-2000 Plant Canopy Analyzer measurements (together with a file describing the location of measurement points and height to crown base and height to top of crown at each measurement point) or stem map data for the stand, or both. LITE can be used to calculate the amount of light at any particular date and time or to calculate totals for a desired period of time (i.e., daily, weekly, monthly, seasonally). Both PPFD and fractional transmission can be displayed. Results are displayed to the screen and can be printed or exported to other applications.

The purpose of this report is to document the LITE program. It is intended as both a behavioural description of the program and a users' manual.

2.1 Application Frame Display and Main Menu

The *APPLICATION FRAME* is the main window that appears when the application starts. It is a display workspace used for windows created by the application and houses the *MAIN MENU.* It is also the window that is displayed when all files have been closed by the user.



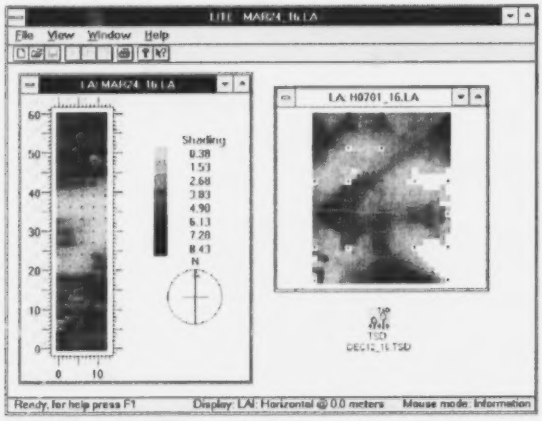
The parts of the window are standard Windows™ elements:

- The **Control-menu box** is used to resize, move, maximize, minimize, and close windows, and switch to other applications. To view this menu, click on the box with a pointing device or type **<Alt+space bar>**.
- The **Title bar** shows the name of the application or document and is highlighted when the window is active.
- The **Window title** is the name of the application or document.
- The **Menu bar** lists the available menu. In this example, the menu options are **File**, **View** and **Help**. To view one of them, either click on the word with a pointing device or type **<Alt+the underlined letter>**.
- Using a pointing device, such as a mouse or Glidepoint™, the user can click the **Maximize button** to enlarge the active application window so that it fills the entire desktop, or click the **Minimize button** to reduce the window to an icon.
- The **Window border** is the outside edge of a window. The border can be used to enlarge or shrink a window by dragging the corner or border with a pointing device. Position the pointing device over the border, click and hold on the left button and then drag the border by moving the pointing device without releasing the button. When the window is sized appropriately, release the button.
- The **Toolbar** displays buttons under the main menu which can be used for quick access to commonly used commands if the user has a pointing device such as a mouse or Glidepoint™.

- The **Status bar** at the bottom of the window displays information about the active document or highlighted command. The Status bar also shows the state of the **CapsLock**, **NumLock** and **ScrollLock** keys. The example above shows **NumLock** is activated.
- The Workspace holds any windows created by the application. These are called *child windows* and are limited by the borders of the application frame. Any child windows reduced to icons are kept on this workspace and are managed by the application frame.

2.2 Multiple Document Interface

The program supports multiple instances of files using the Windows™ *Multiple Document Interface (MDI)*. Each file is displayed in its own child window inside the application frame. The title bar of the active child window is displayed with the colours that Windows™ uses to denote a highlighted title bar (these colours will vary depending on how the system is set up). The active child window (the one with the focus) is also referred to as the current window. The menu bar changes depending upon the type of file (leaf area or tree stand) displayed by the active window, and any commands invoked from the menu bar will affect only the active window. The name of the file displayed by the active window is also displayed on the title bar of the application frame. The program also supports multiple views of a file which allows the user to see both a display of the Leaf Area and of the Leaf Area Index of the same file concurrently.



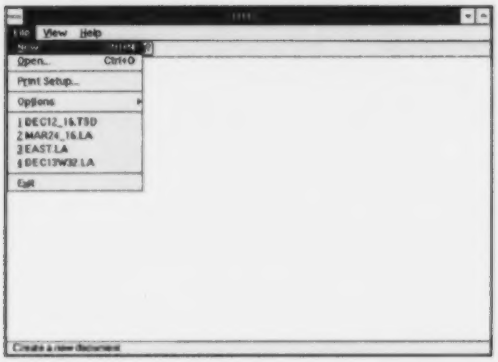
In the example above, the active child window is displaying the file **MAR24_16.LA** and the LA menu bar is displayed. Also shown are an inactive child window displaying the file **H0701_16.LA**, and the file **DEC12_16.TSD**, reduced to an icon. The file **DEC12_16.TSD** can be activated by double-clicking on it with a pointing device or by selecting it from the **Window** menu. This will cause the active window to become inactive, the icon to change into the active window, and the TSD menu bar to be displayed.

3.1 Main Menu

The *MAIN MENU* consists of three choices for user interaction: **File, View** and **Help.** The **File** menu controls data input and output from the program. The **View** menu controls the display of tool bars and status bars. The **Help** menu displays information about the program and supports the user with on-line help.

3.1.1 File Menu

Allows the user to perform standard Windows™ file operations. With no files open, the user is restricted to one of five choices: (1) creating a new file (**New**); (2) opening an existing file (either with **Open** or by selecting a file from the file list, if one exists); (3) setting up the printer for subsequent print jobs (**Print Setup**); (4) setting global program options which define the way LITE will operate (**Options**); and (5) or exiting the program (**Exit**). The bottom section of this menu shows the last four files (TSD or LA) that were opened or saved.



New

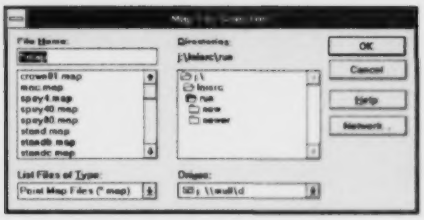
There are two file-types that can be created: Leaf Area (LA) or Tree Stand (TSD). The user is first prompted with the type of document to be created. Next, the user is prompted to provide the name of an observation point map file (see **Observation Point Map File (*.map)** on page 17). The new file is named "untitled". Some grayed-out menu items become available after a file is created or loaded.

Document Type Prompt

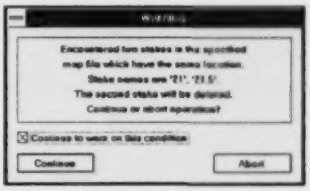
This dialog box prompts the user for the type of document to create. Currently, the user may create either a new LA document or a new TSD document.

Observation Point Map File Prompt

This dialog box prompts the user for the name of the observation point map data. The observation point data is read from the file and interpreted. See the section **Observation Point Map File (*.map)** on page 17 for specifications and information on these files. The appearance of the dialog box used to input the filename will vary depending on the version and configuration of Windows™. If there are any errors on input, the user is notified by a pop-up dialog box.



If the warning option "Report when a duplicate stake in a map file is found" is enabled and the program encounters two stakes with the same location, a warning box will appear on the screen informing the user of this condition and prompting them to either continue (deleting the second stake) or abort the operation.

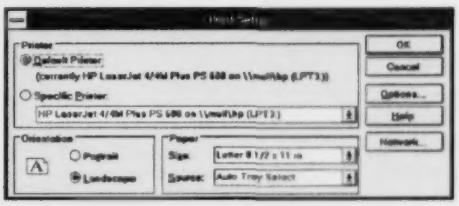


Open

Inputs an existing file. The file is loaded into the program and displayed on the screen in a new window. The user can begin operations on the loaded file. Previously loaded index files are unaffected by this operation. The dialog box that appears will be very similar to the one used to input the map file name (page 6) but will default to files with an extension of **`la`** or **`tsd`**.

Print Setup

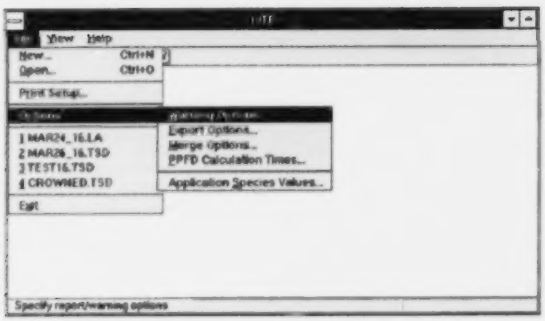
The user is prompted to select a printer and given the option to redirect print output to a file instead of a device. The is a standard dialog box in the Windows™ environment.



Options

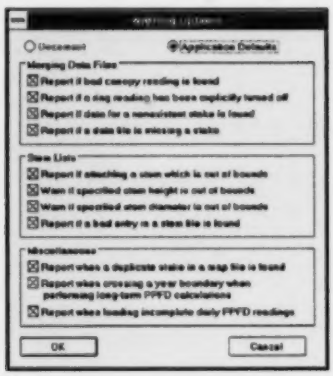
The Options menu item controls optional behaviour of the program such as warning about input conditions, the default behaviour of tree species, and

other behaviours. They are detailed below.



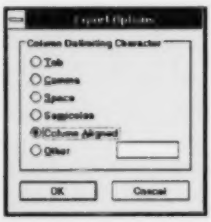
Warning Options

The Warnings Options dialog box allows the user to specify which error conditions to report. Only the application default behaviour can be accessed from the opening panel, as no documents are loaded. Hence the **Document** button is disabled.



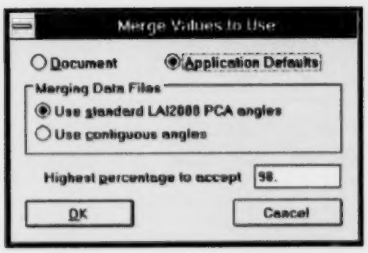
Export Options

The user can export various types of data, as described in the TSD portion of this document. The options in this dialog box specify the formatting of the export files. Either a special character can be used to separate columns of data (e.g., a comma), or the user can choose to align the columns.



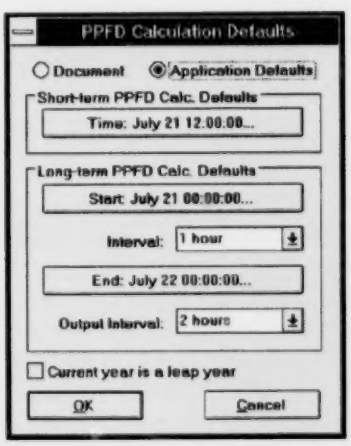
Merge Options

The standard LAI2000 PCA angles have slight gaps between the rings. The user has the option of using either the LAI2000 PCA angle specification or LITE's angle specification (which eliminates the gaps) when the .DAT files are merged. The **highest percentage to accept** value specifies the break-over point at which the associated leaf area is deemed to be so minimal that it should be eliminated. This value is used to mark the area of the crown space as having no leaf area in an effort to more accurately represent the original crown space of the stand by affecting the distribution of data in the .DAT files.



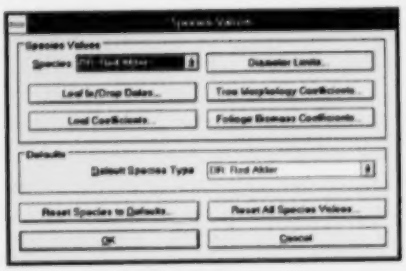
PPFD Calculations

This dialog lets the user specify the initial times and accuracy for PPFD calculations when documents are initially created or re-opened. If a TSD document is open, the user can choose between document and application defaults. The **Short-term PPFD Calc. Defaults** button allows users to specify the default time used for instantaneous calculations. The **Long-term PPFD Calc. Defaults** section allows users to specify the start and end dates for long-term calculations, along with a time interval for both the calculations and output of those calculations. If **Current year is a leap year** is checked, PPFD calculations (after February 27th) will be adjusted to take the extra day into account. For example, if the user checked the box below, the short-term time would be adjusted to read July 20 and the long-term interval would be adjusted to start on July 20 and end July 21 and all PPFD calculations would be adjusted accordingly. This option can be set at both the document and at the application level.



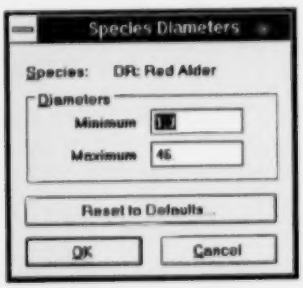
Application Species Values

Users have the ability to alter the default species coefficients at the application level. When a new document is created, it inherits the species coefficients from the application. Users who wish to change the species coefficients for all new documents should change these values using the **Application Species Values** menu option. Users who wish to change the species coefficients for a single document should use the **Document Species Values** menu option. The sequence of dialog boxes and options are the same for both the **Application Species Values** and the **Document Species Values** and are shown below. Each species has its own set of values, and may have different dialog boxes to support different formulas. When this dialog is first opened, there is no species in the **Species** box, and the associated buttons are disabled.



Diameter Limits

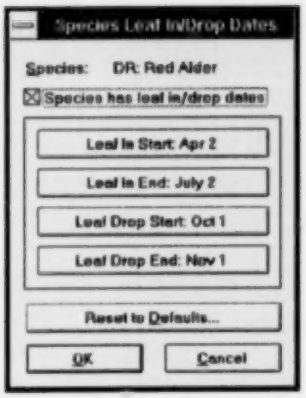
This dialog box allows the user to select a minimum and maximum diameter limit for stems. These values are used to validate stem diameters when they are imported from a file.



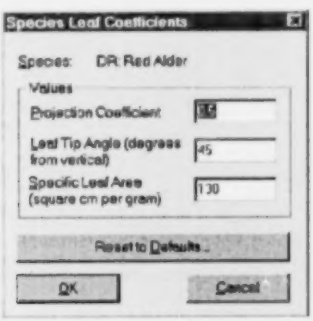
Leaf In/Drop Dates

Users can specify the leaf in and leaf drop behaviour for each species in their area. The program assumes that there are no leaves before the **Leaf In Start** date and no leaves after **Leaf Drop End** date. Between the **Leaf In End** and **Leaf Drop Start** dates, the program assumes that all leaves are fully developed. Between the start and end dates for Leaf In and Leaf Drop, the

program uses linear interpolation to calculate leaf areas. If **Species has leaf in/drop dates** is unchecked, that particular species will have a constant canopy year-round and the buttons to change the leaf in/drop dates will be disabled.



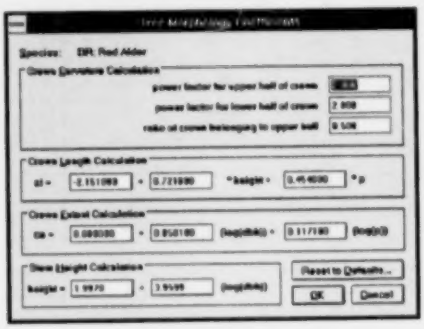
The following graph illustrates the methodology used. Before *leaf in start*, there are no leaves (the ratio of full leaf in values is 0). Between *leaf in start* and *leaf in end*, the program calculates the ratio as a value increasing from 0 to 1. Between *leaf in end* and *leaf drop start*, the leaves are fully developed (the ratio of full leaf in values is 1). Between *leaf drop start* and *leaf drop end*, the program calculates the ratio as a value decreasing from 1 to 0. And, after *leaf drop end*, there are again no leaves.



Tree Morphology Coefficients

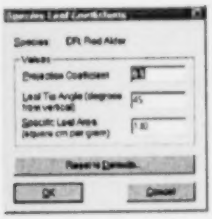
These coefficients are used to determine the dimensions of the crown of each species of tree. Depending on how much data the user has provided for each stem, the values specified in this dialog box may not be used for all stems. For example, the crown extent for each quadrant can be specified by the user. If the user has specified crown extent values, they will be used in place of the formula and coefficients specified in this dialog box. The **Crown Curvature Calculation** section allows the user to define the actual shape of the crown.

The **power factor for upper half of crown** refers to the shape of the upper half of the crown, **power factor for lower half of crown** refers to the shape of the lower half, and **ratio of crown belonging to upper half** defines the boundary for the upper and lower halves of the crown. For more information on how these values affect crown shape, see **5.4.3 Crown Generation page 87**. In the following example, "cl" stands for crown length, "ce" for crown extent, "height" for stem height, "dbh" for diameter at breast-height, "p" for the distance to the closest tree in the specified quadrant, and "log" to natural logarithms.



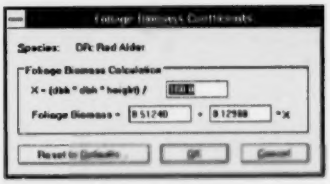
Leaf Coefficients

These values are used by different formulas in the program. The **Projection Coefficient** is used to determine how much light is intercepted by the leaves of the given species. The **Leaf Tip Angle** is used to determine the vertical projection of leaf area and the **Specific Leaf Area** is used to convert foliage biomass to leaf area.



Foliage Biomass Coefficients

These coefficients are used to determine the amount of leaf area associated with stems during crown generation, which takes place in the TSD portion of LITE. As different equations are required for different species, different dialog boxes will appear depending on which species were selected. The following shows the dialog box used for Red Alder, where "dbh" is the diameter at breast-height and "height" is the current height of the tree.

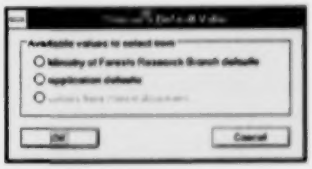


Default Species Type

Any area in a TSD document which is not associated with a tree uses the default species information for PPFD calculations. This allows PPFD to be calculated even when the canopy is only partially (or not at all) associated with trees.

Reset Species to Default

The users have the ability to quickly change species values back to a default state, allowing users to correct mistakes or to apply values for a specific region, tested in one document, to the application default values. A choice is given among **Ministry of Forests Research Branch defaults** (which cannot be modified), **application defaults** (which are saved in LITE's INI file), or **values from the current document** (this option is only enabled if a valid TSD document is currently open).



Reset All Species Values

This option allows the user to reset all of the species values to a default. Whereas 'Reset Species to Default' changes all of the values associated with one species, this option will change all the values of all the species to the set of defaults selected by the user. The dialog box used for this option is identical to that used for the "Reset Species to a Default" option (above).

File List

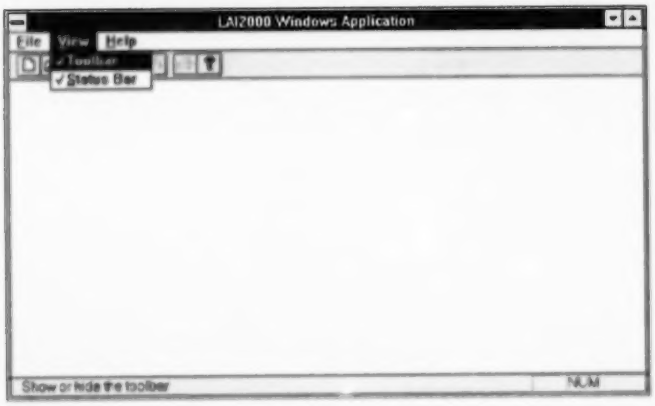
The four files most recently opened or saved are listed. The user may open one of these files by selecting it.

Exit

The program exits to the Windows™ environment.

3.1.2 View Menu

Selecting **Toolbar**, or **Status Bar** causes a check mark to appear beside the option on the menu. These options can be selected at the same time, allowing the user to display both on the screen.

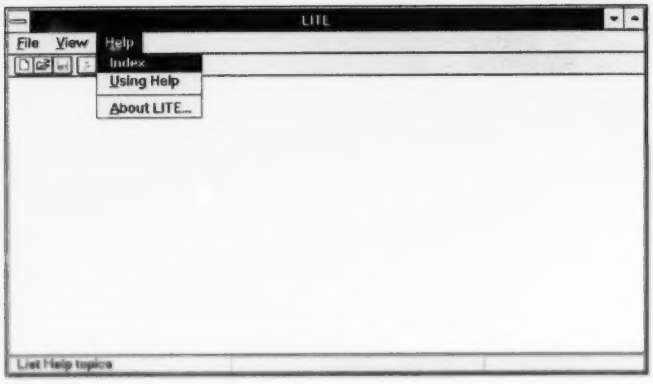


Toolbar
Selecting this item from the menu will toggle the toolbar on the main window. The toolbar, a group of buttons located directly under the main menu, can be used for quick access to commonly used commands if the user has a pointing device such as a mouse or Glidepoint™.

Status Bar
Selecting this item from the menu will toggle the status bar. The status bar, located at the bottom of the main window, provides information about the active document or highlighted command and also shows the state of the **CapsLock**, **NumLock** and **ScrollLock** keys.

3.1.3 Help Menu

This menu displays program information and supports the user with on-line help. **Index** brings up a list of topics pertaining to LITE. **Using Help** brings up information on how to use the Help menu system. **About LITE** brings up the about-box for the program.



Index

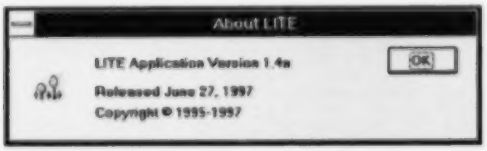
Displays a list of Contents for the **Help**. The user can choose one of the topics by clicking on it with a pointing device or by selecting it with the **Tab** key and then pressing **Enter**.

Using Help

This is a standard feature in the Windows™ environment. It explains how to use **Help**.

About LITE

Displays information about the program, including version number and copyright.



This part of the program calculates the leaf area (**LA**) contained in each cubic meter space and maps the distribution of LA within the stand. It combines the light observations from an LAI 2000 Plant Canopy Analyzer (PCA) with data associated with the observation point. The LA of the stand can be displayed on the screen, printed, and/or recorded in a file.

The canopy of a stand is divided into one metre cubes. The cubes that affect each PCA measurement point are identified and the LA of each cube is determined and recorded. The axes for the cube space are aligned with the users' plot area. Multiple light observation files can be combined or merged into a single set of LA cubes.

LA can be displayed on the screen by the user. The view of the canopy is determined by the user and is limited to either horizontal or vertical planes. Additionally, vertical planes must parallel one of the user's plot axes.

The sum of the LA in a vertical stack of cubes is the leaf area index (**LAI**) of the point under the stack. These values can be displayed on the screen in the same format as LA or, additionally, written to a file for further use.

The program can display more than one plot on the screen at a time. It uses the Windows™ Multiple Document Interface (**MDI**) to display and manage more than one plot at a time. Multiple views of a document are also supported, allowing the user to view the LA and the LAI of the same plot in different child windows at the same time.

4.1 File Formats

4.1.1 Input Files

When working with LAI 2000 PCA data, the program requires both the PCA data files and an observation point map file that provides information on the location of each measurement point. The calculation of LA requires information on the location of the base and top of the canopy at each point. This is included in the observation point map file.

Observation Point Map File (*.map)

The observation map file has 3 functions:

1. It contains an azimuth reading in degrees (from true North) of the vector from the origin to point (0,1) of the sample grid. The program uses this value to orient the user's coordinate-space with compass readings (True North).
2. It maps observation labels contained in the LAI 2000 light observations file to (x,y) coordinates in metres. These coordinates are the points in the plot where the observations were taken.
3. It contains the canopy data. Two heights, in metres, are needed for each observation point, the height to the base of the crown and the height to the top of the canopy.

The file format is as follows:

<azimuth of (0,1)>
<label> (<x>, <y>) <height to crown base> <height to top of canopy>
<label> (<x>, <y>) <height to crown base> <height to top of canopy>
<label> (<x>, <y>) <height to crown base> <height to top of canopy>
...

where:

<azimuth of (0,1)>	::=	integer (0, 360)
<label>	::=	character*7
<x>	::=	float (0, 100)
<y>	::=	float (0, 100)
<height to crown base>	::=	float (0, 100)
<height to top of canopy>	::=	float (0, 100)

The program looks for a filename extension of `map` for these files. The user may override the default and use any filename extension. An example of this file can be found in **Appendix C - Observation Point Map File (*.map)**, page 93.

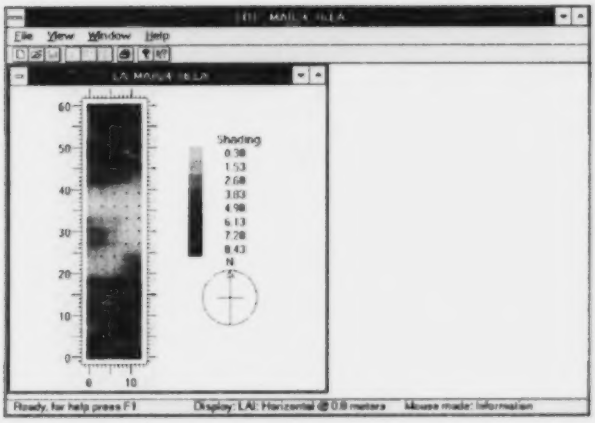
LAI 2000 Light Observations File (*.dat)
The format of these files is the same as that found in the LAI 2000 users' guidebook. The program expects only one light observation per observation point. If there is more than one observation at a point, the program will use the last observation for that point. By default, the program looks for files with an extension of `dat`. The user may override this default and use any filename extension. The program matches "RSPS2" values in PCA data files with the label given to specific grid points on the map file. The user should be careful to ensure that matching labels are used in each file for each data point.

4.1.2 Input/Output Files

Leaf Area File (*.la)
The leaf area file is the product of this part of the program. The program has the ability to read and write these files. Work in progress can be saved and recalled for further processing. Completed files can be recalled for display and printing. The leaf area file is also used in other parts of this program.

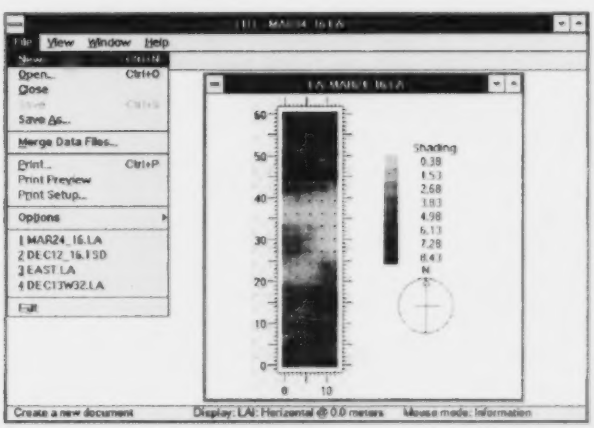
4.2 LA Main Menu

The *LA MAIN MENU* consists of four choices for user interaction: **File, View, Window** and **Help.** The **File** menu controls data input and output from the program. The **View** menu allows the user to select how the data will be presented. The **Window** menu presents users with standard **MDI** options to control windows created by the program. The **Help** menu displays information about the program and supports the user with on-line help.



4.2.1 File Menu

This menu allows the user to perform standard Windows™ file operations on leaf area (LA) files. **New** allows LA files to be created. **Open** opens an existing LA file. **Close** closes an open LA file. **Save** and **Save As** allows users to save open LA files without closing them. **Merge Data Files** combines light observations into the current LA file. **Print** prints the current file, **Print Preview** allows users to check the output before it is printed, and **Print Setup** allows users to set printer options for subsequent print jobs. The **Options** menu item opens up another menu of choices which allow users to set program options which define the way LITE will operate. **Exit** will exit the program. The bottom section of this menu shows the last four files (LA or TSD) that were opened or saved.

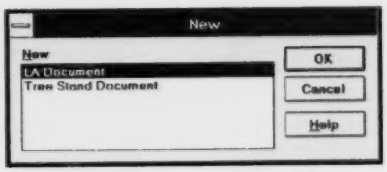


New

There are two file-types that can be created: Leaf Area (LA) or Tree Stand (TSD). The user is first prompted with the type of document to be created. Next, the user is prompted to provide the name of an observation point map file (see **Observation Point Map File (*.map)** on page 17). The new file is named "untitled". Some grayed-out menu items become available after a file is created or loaded.

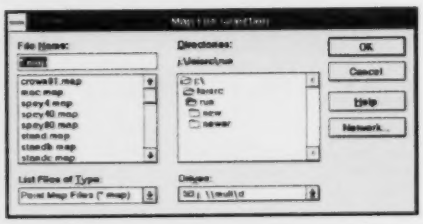
Document Type Prompt

This dialog box prompts the user for the type of document to create. Currently, the user may create either a new LA document or a new TSD document.

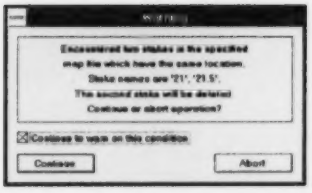


Observation Point Map File Prompt

This dialog box prompts the user for the name of the observation point map data. The observation point data is read from the file and interpreted. See the section **Observation Point Map File (*.map)** on page 17 for specifications and information on these files. The appearance of the dialog box used to input the filename will vary depending on the version and configuration of Windows™. If there are any errors on input, the user is notified by a pop-up dialog box.



If the warning option "Report when a duplicate stake in a map file is found" is enabled and the program encounters two stakes with the same location, a warning box will appear on the screen informing the user of this condition and prompting them to either continue (deleting the second stake) or abort the operation.



Open

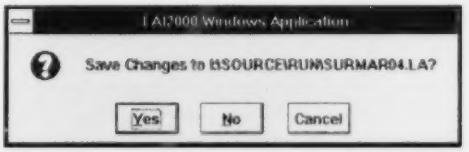
Inputs an existing LA or TSD file. The file is loaded into the program and displayed on the screen in a new window. The user can begin operations on the loaded file. Previously loaded files are unaffected by this action. The dialog box that appears will be very similar to the one used to input the map file name (page 20) but will default to files with an extension of `la` or `tsd`.

Close

The current LA file is closed and its window in the program is removed. If the file has changed since it was last saved, the user is prompted to save the changes or discard them.

Save Changes on Close Prompt

The user is prompted to save or discard the changes made to the LA file. The **No** button does not save any changes made since the last time the file was saved. The **Yes** button on the panel saves the changes to the current file name. The **Cancel** button will remove the message box from the screen and cancel the ***Close*** request.

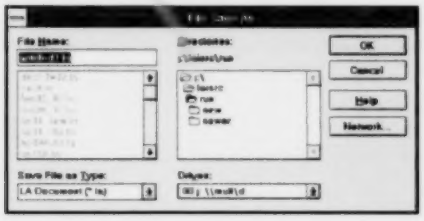


Save

The current LA file is saved to the disk. If it is a newly-created LA file, the program will pop up the ***Save As*** dialog box, and the user is prompted for a new file name.

Save As

The current LA file is saved to the disk. The user is prompted for the name of the file. The current file name is supplied as a default. The user can override the default and save the data in a different file.



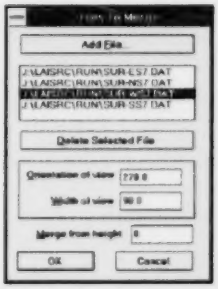
Merge Data Files

The ***Merge Data Files*** menu item is used to combine LAI 2000 light observations into the current LA file. The user is prompted for the names of files that contain the observations. The files are read and the data is interpreted and merged into the current LA file.

Files to Merge

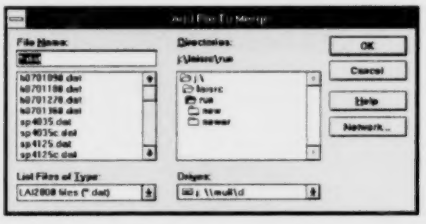
When the ***Merge Data Files*** option is selected, users are presented with a ***Files to Merge*** dialog box. It is from this box that a list of files is constructed, one at a time, by pressing the '**Add File...**' button. Files can also subsequently be deleted by pressing the **Delete Selected File** button. When the list is complete, the user must specify a view orientation and width as well as the height that the light readings were taken. The default value is ground level, and is assumed to be zero.

An example of a completed Files to Merge dialog box is shown below. The user has selected a file called J:\LAISRC\RUN\SUR-WS7.DAT and files merge angles are shown in the dialog box. Note that each file has its own merge angles but all files share a single merge height.



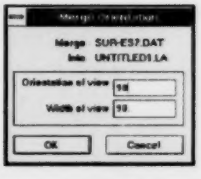
Add File to Merge

When the user presses the '**Add File...**' button on the ***Files to Merge*** dialog box, a file-browser dialog will appear, prompting the user for a filename. They are then prompted for information about the data in that file, after which it is added to the list in the ***Files to Merge*** dialog box.



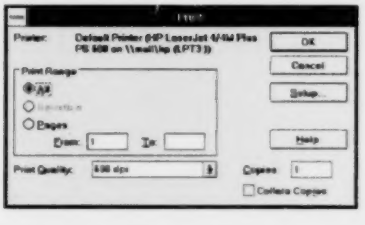
Merge Orientation Prompt

After the user has selected a file from the ***Add File to Merge*** dialog box, the user is prompted for the orientation and for the angular width of the light observation data in the file to be merged. Both values are in degrees, the former is the azimuth of the centre of the field of view for the LAI-2000 from true north and the latter is absolute degrees. The user types the information on the panel, and it is checked for validity. The program assumes the orientation given is the centre of the angular width. After pressing the **OK** button, the program returns to the ***Files to Merge*** dialog box, with the newly-selected file added to its list.



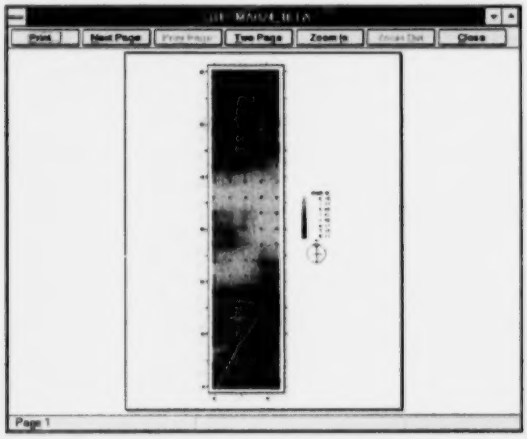
Print

The default printer is displayed, and the user is prompted to select the print range and quality. This is a standard dialog box in the Windows™ environment.



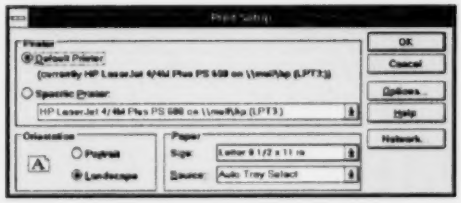
Print Preview

Displays the current page as it will appear when printed. This is a standard tool in the Windows™ environment.



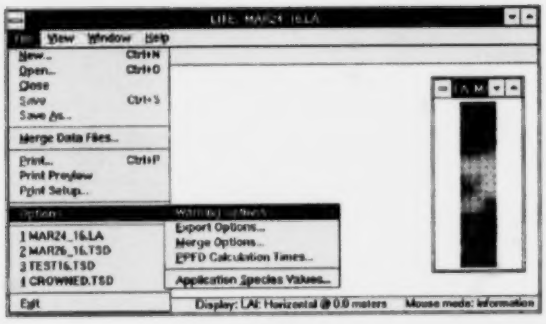
Print Setup

This dialog box prompts the user to choose a printer and provides paper orientation and size options. It is a standard dialog box in the Windows™ environment.



Options

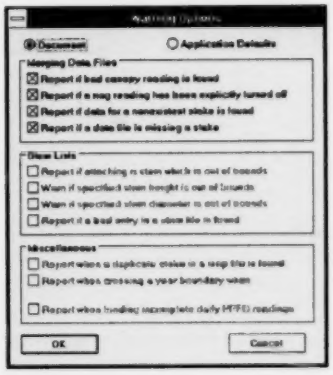
The Options menu item controls optional behaviour of the program such as warning about input conditions, the default behaviour of tree species, and other behaviours. They are detailed below.



Warning Options

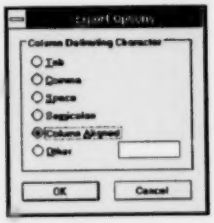
The program can report warnings for erroneous input conditions that may arise when merging data into the current LA file. The user can choose to have these conditions reported or not. The application defaults are stored in the program's initialization file. The disabled options in the panel do not apply to this part of the program.

The **Document** and **Application Defaults** buttons permit the user to store the state of these options. When the Application Defaults button is selected, the state of the input warnings are saved to the initialization file and will be used for data added to any other stands. When the Document button is selected, changes to the Warning Options are not kept. The input warnings are applied only to the current stand.


Document
Application Defaults
Merging Data Files
Report if bad canopy reading is found
Report if a neg reading has been explicitly turned off
Report if data for a nonexistent stake is found
Report if a data file is missing a stake
Plot Limits
Miscellaneous
OK
Cancel

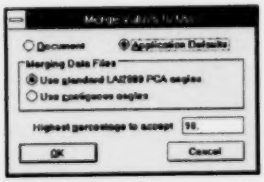
Export Options

The user can export various types of data, as described in the TSD portion of this document. The options in this dialog box specify the formatting of the export files. Either a special character can be used to separate columns of data (e.g., a comma), or the user can choose to align the columns.



Merge Options

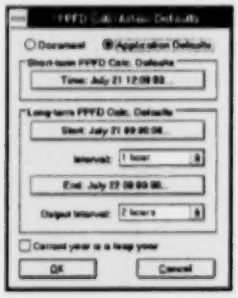
The standard LAI2000 PCA angles have slight gaps between the rings. The user has the option of using either the LAI2000 PCA angle specification or LITE's angle specification (which eliminates the gaps) when the .DAT files are merged. The **highest percentage to accept** value specifies the break-over point at which the associated leaf area is deemed to be so minimal that it should be eliminated. This value is used to mark the area of the crown space as having no leaf area in an effort to more accurately represent the original crown space of the stand by affecting the distribution of information in the .DAT files.



PPFD Calculations

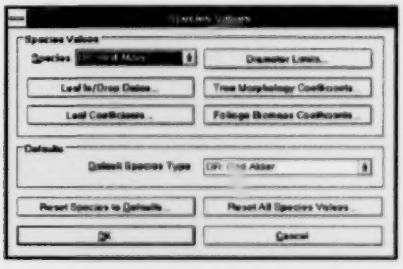
This dialog lets the user specify the initial times and accuracy for PPFD calculations when documents are initially created or re-opened. If a TSD document is open, the user can choose between document and application defaults. The "Short-term PPFD Calc. Defaults" button allows users to specify the default time used for instantaneous calculations. The "Long-term PPFD Calc. Defaults" section allows users to specify the start and end dates for long-term calculations, along with a time interval for both the calculations and output of those calculations. If **Current year is a leap year** is checked, PPFD calculations (after February 27th) will be adjusted to take the extra day into account. For example, if the user checked the box below, the short-term time would be adjusted to read July 20 and the long-term interval would be

adjusted to start on July 20 and end July 21 and all PPFD calculations would be adjusted accordingly. This option can be set at both the document and at the application level.



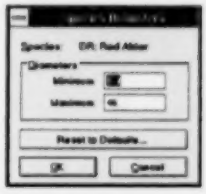
Application Species Values

Users have the ability to alter the default species coefficients at the application level. When a new document is created, it inherits the species coefficients from the application. Users who wish to change the species coefficients for all new documents should change these values using the **Application Species Values** menu option. Users who wish to change the species coefficients for a single document should use the **Document Species Values** menu option. The sequence of dialog boxes and options are the same for both the **Application Species Values** and the **Document Species Values** and are shown below. Each species has its own set of values, and may have different dialog boxes to support different formulas. When this dialog is first opened, there is no species in the **Species** box, and the associated buttons are disabled.



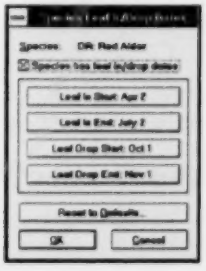
Diameter Limits

This dialog box allows the user to select a minimum and maximum diameter limit for stems. These values are used to validate stem diameters when they are imported from a file.

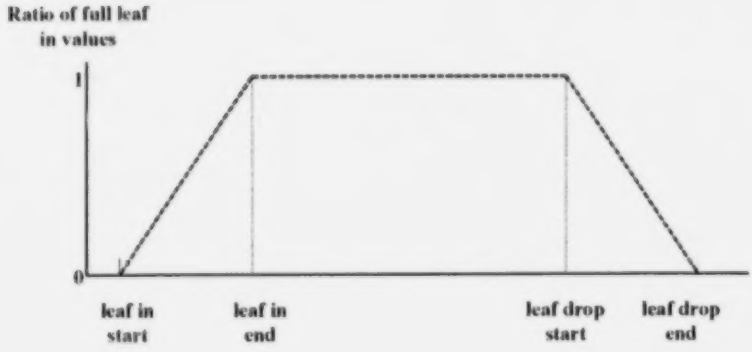


Leaf In/Drop Dates

Users can specify the leaf in and leaf drop behaviour for each species in their area. The program assumes that there are no leaves before the **Leaf In Start** date and no leaves after **Leaf Drop End** date. Between the **Leaf In End** and **Leaf Drop Start** dates, the program assumes that all leaves are fully developed. Between the start and end dates for Leaf In and Leaf Drop, the program uses linear interpolation to calculate leaf areas. If **Species has leaf in/drop dates** is unchecked, that particular species will have a constant canopy year-round and the buttons to change the leaf in/drop dates will be disabled.

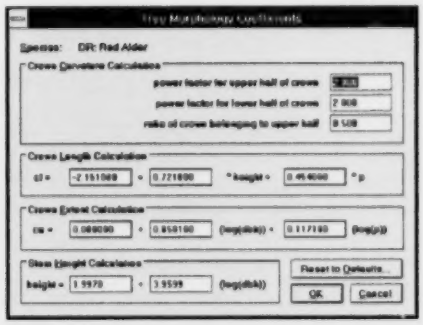


The following graph illustrates the methodology used. Before *leaf in start*, there are no leaves (the ratio of full leaf in values is 0). Between *leaf in start* and *leaf in end*, the program calculates the ratio as a value increasing from 0 to 1. Between *leaf in end* and *leaf drop start*, the leaves are fully developed (the ratio of full leaf in values is 1). Between *leaf drop start* and *leaf drop end*, the program calculates the ratio as a value decreasing from 1 to 0. And after *leaf drop end*, there are again no leaves.



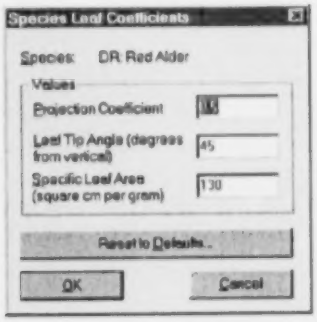
Tree Morphology Coefficients

These coefficients are used to determine the dimensions of the crown of each species of tree. Depending on how much data the user has provided for each stem, the values specified in this dialog box may not be used for all stems. For example, the crown extent for each quadrant can be specified by the user. If the user has specified crown extent values, they will be used in place of the formula and coefficients specified in this dialog box. The **Crown Curvature Calculation** section allows the user to define the actual shape of the crown. The **power factor for upper half of crown** refers to the shape of the upper half of the crown, **power factor for lower half of crown** refers to the shape of the lower half, and **ratio of crown belonging to upper half** defines the boundary for the upper and lower halves of the crown. For more information on how these values affect crown shape, see **5.4.3 Crown Generation, page 87**. In the following example, "cl" stands for crown length, "ce" for crown extent, "height" for stem height, "dbh" for diameter at breast-height, "p" for the distance to the closest tree in the specified quadrant, and "log" to natural logarithms.



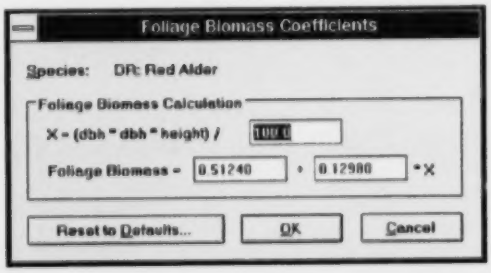
Leaf Coefficients

These values are used by different formulas in the program. The **Projection Coefficient** is used to determine how much light is intercepted by the leaves of the given species. The **Leaf Tip Angle** is used to determine the vertical projection of leaf area and the **Specific Leaf Area** is used to convert foliage biomass to leaf area.



Foliage Biomass Coefficients

These coefficients are used to determine the amount of leaf area associated with stems during crown generation, which takes place in the TSD portion of LITE. As different equations are required for different species, different dialog boxes will appear depending on which species were selected. The following shows the dialog box used for Red Alder, where "dbh" is the diameter at breast-height and "height" is the current height of the tree.



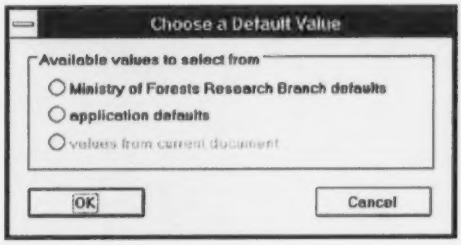
Default Species Type

Any area in a TSD document which is not associated with a tree uses the default species information for PPFD calculations. This allows PPFD to be calculated even when the canopy is only partially (or not at all) associated with trees.

Reset Species to Default

Allows users to change species values back to a default state, allowing users to correct mistakes or to apply values for a specific region, tested in one document, to the application default values. A choice is given among **Ministry**

of Forests Research Branch defaults (which cannot be modified), **application defaults** (which are saved in LITE's INI file), or **values from the current document** (this option is only enabled if a valid TSD document is currently open).



Reset All Species Values

This option allows the user to reset all of the species values to a default. Whereas 'Reset Species to Default' changes all of the values associated with one species, this option will change all the values of all the species to the set of defaults selected by the user. The dialog box used for this option is identical to that used for the "Reset Species to a Default" option (above).

File List

The four most recently opened or saved files are listed. The user may open one of these files by selecting it.

Exit

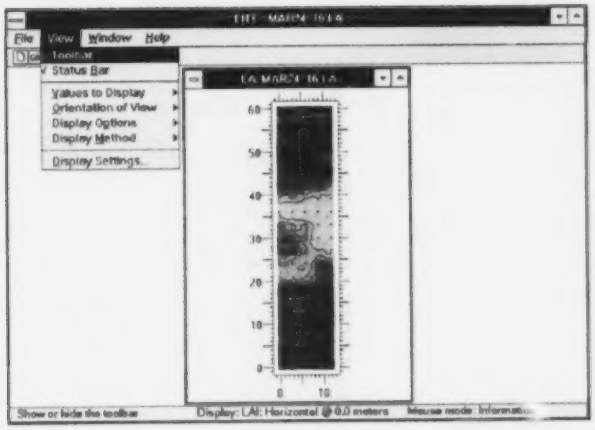
The program exits to the Windows™ environment. The program checks all open LA or TSD files for changes, and prompts the user to save or discard changes before exiting.

Save Changes on Exit Prompt

The user is prompted to save or discard the changes made to any open LA or TSD files. The dialog box that appears is similar to the one that is used for the ***Save Changes Prompt*** for the ***Close*** menu option above. The **Cancel** button will remove the ***Save Changes Prompt*** dialog box from the screen and cancel the ***Exit*** request.

4.2.2 View Menu

The options on this menu allow users to change the look of the display. Selecting **Toolbar** or **Status Bar** causes a check mark to appear beside the option on the menu. These options can be selected at the same time, allowing the user to display both on the screen. **Values to Display** changes what data is displayed in the current window. **Orientation of View** changes what part of the data is displayed in the current window. These menu items are mutually exclusive within their section (only one view and one type of data may be seen in a window at a time). **Display Options** annotates the display of the current window. **Display Method** controls how the data is displayed. None, one, or many of these options can be selected at a time. **Display Settings** gives the user a centralized location (a single dialog box) from which to modify all the view-options at once.



Toolbar
Selecting this item from the menu will toggle the toolbar on the main window. The toolbar, a group of buttons located directly under the main menu, can be used for quick access to commonly used commands if the user has a pointing device such as a mouse or Glidepoint™.

Status Bar
Selecting this item from the menu will toggle the status bar. The status bar, located at the bottom of the main window, provides information about the active document or highlighted command and also shows the state of the **CapsLock**, **NumLock** and **ScrollLock** keys.

Values to Display
Selecting this menu item brings up a list of options from which the user can specify the data to be displayed. Only one option, which will have a check mark beside it, can be selected at a time.

LA (Leaf Area)

Draws a map of **LA** on the screen. The **LA** is calculated for each square meter of the current view and is displayed in the current window. The **LA** view is a one metre thick horizontal or vertical slice of the canopy.

LAI (Leaf Area Index)

Draws a map of **LAI** on the screen. The **LAI** is calculated for each square meter of the current view and is displayed in the current window. **LAI** is defined as the sum of the **LA** *above* the current display elevation.

 # Measurements per Cube

The number of measurements or observations that were used to determine the **LA** of each cube is displayed in the current window. This option displays values for a one metre thick horizontal or vertical slice of the canopy.

Orientation of View
Selecting this menu item brings up a list of options, from which the user can choose a particular "orientation" (horizontal or vertical) for the data. Only one

option, which will have a check mark beside it, can be selected at a time.

Horizontal View

This choice will draw a map of a plane parallel to the earth's surface intersecting the canopy. The user is prompted to select the height of the view above the ground in metres. The maximum and minimum crown heights are displayed in the dialog box to assist the user in making their selection. The program then displays the data values (LAI, LA or # of measurements) of the layer of cubes that are the selected distance above the ground.

Vertical View

This choice will draw a map of a plane perpendicular to the earth's surface intersecting the canopy. The plane must be parallel to one of the user's axes. The user is prompted to select either **Up to Down** (parallel to the Y-axis) or the **Left to Right** (parallel to the X-axis), and the **Coordinate** (distance from the origin) of the view in metres. The plot boundaries are displayed in the dialog box to assist the user in making their selection. The program displays the data values of the wall of cubes that are the selected distance from the origin of the plot.

Display Options

Selecting this menu item brings up a list of options from which the user can choose various elements to display as part of the output. Any options were selected will have a check mark displayed beside them on the menu. If the user subsequently deselects an option, the check mark associated with that option will be erased. More than one option can be selected at a time, allowing the user to overlay various elements on the screen display, or on the printed output.

Show Stake Positions

Displays the positioning of the observation points read from the **map** file. These are the points at which the canopy heights are measured and the LAI

2000 PCA readings were taken in the stand. Typically, stakes are driven into the ground at these points.

Show Legend

Displays a shading legend consisting of eight display values (either colours or patterns) and the actual data values used to create the display values. The shading legend is displayed beside the actual display. Although only eight colours are shown on the legend, sixty-four colours are actually used to paint the display map.

Show Ruler

This option will display a border around the display of the plot. The border is annotated with the size of the plot. This is useful when attempting to determine the location of artifacts in the plot or when deciding offsets and distances for views.

Display Method

Selecting this menu item brings up a list from which the user can control how the data is displayed. Any options which have been selected will have a check mark displayed beside them on the menu. If the user subsequently deselects an option, the check mark associated with that option will be erased. More than one option can be selected at a time, allowing the user to overlay colours, patterns, and isolines on the screen display, or on the printed output.

Colour

Shades the map in the current window with colour. Colours do not overwrite patterns nor isolines. Colours will not appear on printed output. Instead, colours will be translated to patterns or grey scales.

Pattern

Uses patterns to shade the current map. Patterns are drawn over colours on the screen but not over the isolines.

Isolines

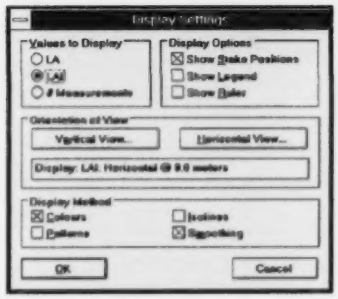
Puts isolines on the current map. Isolines are drawn over any colours or patterns currently on the screen.

Smoothing

Blurs the boundaries between the cubes displayed on the map using an algorithm which calculates the output-value of a given point on the map by taking the output-value of the cube in which the point resides and adjusting it according to its proximity to its neighbouring cubes. The further from the center of any given cube, the more the new output-value will be adjusted. This results in a smoother-looking output.

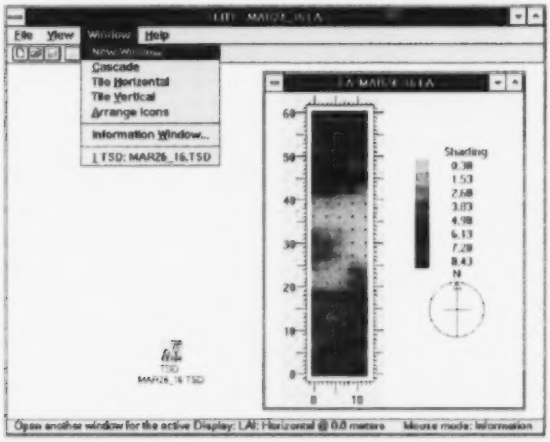
Display Settings

As an alternative to menu toggles, a dialog box is available to make many changes to the display from a centralized location.



4.2.3 Window Menu

The **Window** menu presents users with standard **MDI** options to control windows created by the program. The **New Window** option creates a copy of the selected window. The **Cascade** option arranges all of the open windows from the top left to the bottom right of the main program window. This allows all of the title bars to be easily read. The **Tile Horizontal** and **Tile Vertical** options arrange the open windows as smaller tiled windows in the main program window. These option are useful for seeing a piece of each of the open windows. The **Arrange Icons** option aligns all of the iconic (minimized) windows in a row at the bottom of the main program window. The **Information Window** toggles a window with information about the selected map. The bottom section of this menu shows all of the open files, whether in an open window or in icon form. The user can select the file of choice using the mouse or the keyboard. The selected window is opened (if minimized), brought to the front, and receives the input focus.



New Window

Creates a copy of the current window and gives it the input focus. The user can then select a different view of the same stand. This is the standard Windows tool for allowing a user to create a new view of the same document.

Cascade and Tile Selections

The Cascade selection causes all of the open windows to be cascaded inside the main application window. After windows have been cascaded, their title bars and system menus are visible and accessible, allowing the user to easily find and display a particular one.

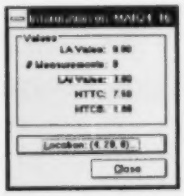
The Tile selection causes all of the *open* windows to be tiled either horizontally or vertically inside the main application window. This is useful for displaying two or more windows at their maximum size simultaneously. The user selects the format, vertical or horizontal, that is most appropriate for viewing their data. If the user has more open windows than they wish to tile, they must minimize the excess windows (making them icons) before selecting Tile.

Arrange Icons

This selection causes all of the minimized windows (icons) inside the application window to be arranged neatly along the bottom of the application window.

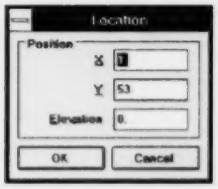
Information Window

This dialog displays basic instantaneous values for a point on the map. From this dialog, the user may specify a different point on the map by pressing the "location" button. This dialog can also be accessed by clicking directly on a point in the map window.



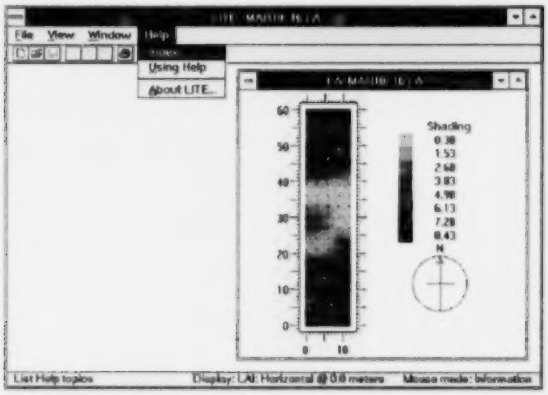
Location

From this dialog, information can be entered to pinpoint a specific map location. The user is prompted to enter the **X** and **Y** coordinates (where 0,0 is in the lower, left-hand corner of the map), along with an **elevation**. Any numbers entered which are out of range will be modified to fit the range of valid data.



4.2.4 Help Menu

This menu displays program information supports the user with on-line help. **Index** brings up a list of topics pertaining to LITE. **Using Help** brings up information on how to use the Help menu system. **About LITE** brings up the about-box for the program.

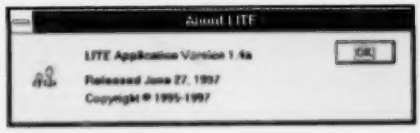


Index
Displays the Contents page for the LAI 2000/Tree Stand Modelling **Help**. The user can choose one of the topics by clicking on it with a pointing device or by selecting it with the **Tab** key and then pressing **Enter**.

Using Help
This is a standard feature in the Windows™ environment. It explains how to use **Help**.

About LITE

Selecting this option displays a dialog box with information about the program, including the version number, copyright and license.



4.3 Calculations and Algorithms

4.3.1 Plot Extents

The plot extents are calculated as a bounding box around the user's plot. The horizontal limits are defined by a rectangle just large enough to hold all of the user's stake positions. The vertical limits are defined by the maximum crown height and minimum height to crown base provided by the user at each stake location in the **map** file.

4.3.2 Canopy Cube and Angular View Intersection

Each PCA measurement provides an estimate of diffuse non-interceptance through a set of canopy cubes. The set of cubes associated with a particle measurement is determined using the geometry of the view. For a single plane of cubes at a known height, h, two arcs are drawn. The outer or larger arc is formed by projecting the lower view angle, l, from the observation point on to the plane of cubes. The inner or smaller arc is formed by projecting the upper view angle, u, on to the plane of cubes. Both projections are constrained by view width and direction entered by the user. The arcs will be complete circles if the user is working with 360° views.

The formula for the inner arc is $r = h \tan u$, centred at the observation point, and the formula for the outer arc is $r = h \tan l$, centred at the same point.

The cubes that lie between these arcs are in the set that will be affected by the light calculations from the observation point. The complete set is formed by enumerating the heights between the base of the crown and the top of the canopy.

4.3.3 Leaf Area Determination

The average leaf area (LA) of the set of cubes that affect an observation is based on the formula from the LAI 2000 PCA handbook (LiCOR Inc. 1993). Formulas from the handbook are for an entire 180° view of the hemisphere.

The following derivation is designed to calculate the foliage density for the field of view of a single PCA sensor ring. From the handbook, foliage density of the hemisphere is

$$\mu = 2\int_{0}^{\pi/2} \frac{-\ln(T(\theta))}{S(\theta)} \sin(\theta) d\theta$$

where:

θ = angle of view of the hemisphere

$T(\theta)$ = gap fraction ratio

$S(\theta)$ = length of ray through canopy approximated by $\frac{1}{\cos(\theta)} z$

z = canopy thickness

By restricting the view to a smaller portion of the hemisphere, the following formula is derived

$$\mu = 2\int_{\theta_l}^{\theta_u} \frac{-\ln(T(\theta))}{S(\theta_c)} \sin(\theta) d\theta$$

where:

θ_l = opening angle

θ_u = closing angle

θ_c = angle of center $\theta_l + \frac{\theta_u - \theta_l}{2}$

Note that the integral is still doubled since the angle of inclusion is encountered twice, once while sweeping upwards and once while sweeping downwards. This is still valid when the viewport of the device is masked, since both the above canopy and below canopy sensors are masked identically and the device uses spatial averaging over the entire hemisphere.

Extracting measurement data from the integral leaves the following formula:

$$\mu = 2\frac{-\ln(T_i)}{S(\theta_c)} \int_{\theta_l}^{\theta_u} \sin(\theta) d\theta$$

The integral portion of this formula, $\int_{\theta_l}^{\theta_u} \sin(\theta) d\theta$, is used to weight the measurement for the portion of sky seen from θ_l to θ_u. By using a weight of 1 in place of this integral, the following formula is attained for the foliage density of the i^{th} ring:

$$\mu = 2\frac{-\ln(T_i)}{S(\theta_c)}$$

$$= 2\frac{-\ln(T_i)}{z}(\cos(\theta_c))$$

Since the annular angles are fixed, a table of constants for each of the rings of the LAI 2000 is used.

i	1	2	3	4	5
θ_u	0	16	32	47	61
θ_l	13	28	43	58	74
θ_c	6.5	22	37.5	52.5	67.5
$c_i = 2(\cos(\theta_c))$	1.9871	1.8544	1.5867	1.2175	0.7654

Lastly, the canopy thickness, z_i, is computed along the center angle, θ_c, in the direction of the view entered by the user. This is accomplished by determining the first entry and last exit of the intersection of this line and the canopy. Then the foliage density for the cubes that affect each of the annular rings can be computed using the following formula:

$$\mu_i = \frac{-\ln(T_i)}{z_i} c_i$$

A running average of the **LA** of each cube is kept along with the number of times the cube was intersected by some angular view. A single cube may be intersected by many observations. The running average will assign as many observations to each cube as possible.

4.3.4 Leaf Area Index

The leaf area index for each square metre can be computed by summing the leaf area of all the cubes directly above the square. This value is leaf area in metres^2 per square metre of ground area.

This section of the program prepares a crown map from tree list data (if available) and calculates *Photosynthetic Photon Flux Densities* ***(PPFD)*** at points in a model stand. The program calculates direct, diffuse and total PPFD. PPFD can be displayed on the screen, printed and recorded in a file.

The canopy of the stand is divided into one metre cubes. The amount of light that penetrates each canopy cell is calculated based on the species that generated the foliage in that cell. The user creates the model stand by specifying tree parameters. Alternately, the program can read in a *Leaf Area* ***(LA)*** file that provides data on the LA in each canopy cell and use the map to calculate the extinction of light through the canopy.

For this section of the program, the user must provide a tree list in the form of a *.stm file (see Stem List File (*.stm), page 42).

PPFD can be displayed on the screen by the user. The view of the canopy is determined by the user and is limited to horizontal or vertical planes. Vertical planes must parallel one of the user's plot axes. Stem maps, crown maps and/or LA maps may be also be shown or printed with the PPFD. *% transmittance* can also be calculated and displayed independently or with PPFD.

The program can display more than one stand on the screen at a time using the Windows™ Multiple Document Interface (**MDI**).

5.1 File Formats

5.1.1 Input Files

Observation Point Map File (*.map)

The observation map file has 3 functions:

1. It contains an azimuth reading in degrees (from true North) of the vector from the origin to (0,1) of the user coordinates. The program uses this value to orient the user's coordinate space with compass reading (True North).
2. It maps observation labels contained in the LAI 2000 light observations file to (x,y) coordinates in metres. These coordinates are the points in the plot where the observations were taken.
3. It contains the canopy data. Two heights are needed for each observation point, the height to the base of the crown and the height to the top of the canopy.

The file format is as follows:

<azimuth of (0,1)>
<label> (<x>, <y>) <height to crown base> <height to top of canopy>
<label> (<x>, <y>) <height to crown base> <height to top of canopy>
<label> (<x>, <y>) <height to crown base> <height to top of canopy>
...

where:

<azimuth of (0,1)>	::=	integer (0, 360)
<label>	::=	character * 7
<x>	::=	float (0, 100)
<y>	::=	float (0, 100)
<height to crown base>	::=	float (0, 100)
<height to top of canopy>	::=	float (0, 100)

The program looks for a filename extension of map for these files. The user may override the default and use any filename extension. An example of this file can be found in **Appendix C - Observation Point Map File (*.map)**, page 93.

Leaf Area File (*.la)
The leaf area file is the product of the LAI 2000 PCA Instrument Interpretation portion of the program. The Crown Generation and Light Modelling portion can read these files and display them as the canopy of a stand.

5.1.2 Input/Output Files

Stem List File (*.stm)
The stem list file describes each tree in the stand. Each tree in the list has the following properties:

- User-ID (valid only for file versions 2 and 4) (ASCII string, up to 8 characters in length)
- 2-3 letter species code:
  - MB Bigleaf Maple
  - EP Paper Birch
  - AT Trembling Aspen
  - AC Black Cottonwood/Balsam Poplar
  - DR Red Alder
  - FIR BC Conifer
- x and y coordinates (metres)
- diameter at breast height (dbh) (mm in file versions 1 and 2; cm in versions 3 and 4)
- lean percent (0 - 90 degrees)
- lean direction (0 - 360 degrees)
- height (metres)
- height to crown base in each of 4 quadrants (N,E,S,W) (metres, ranging from 0 to height)

- crown extent in each of 4 quadrants (N,E,S,W) (metres)
- (projected) leaf area of the tree

The user can provide a subset of the list and have the program generate the missing parameters. Four subsets are currently supported:

- (user-id), species code, x, y, dbh, lean percent and lean direction,
- (user-id), species code, x, y, dbh, lean percent, lean direction, and height,
- (user-id), species code, x, y, dbh, lean percent, lean direction, height and height to crown base.
- (user-id), species code, x, y, dbh, lean percent, lean direction, height and height to crown base, leaf area of tree.

Users are free to mix the subsets for different stems in the same file as exemplified in **Appendix B - Stem List File (*.stm) page 92**.

Any modifications made to the tree list within this section of the program can be output as a modified .stm file.

Open Sky PPFD File (*.pfd)

Open sky PPFD files contain PPFD values from a nearby weather station or recording site. The values are expected on an hourly basis for an entire year.

The program expects three numbers per line, separated by whitespace (blanks or tabs). The first number is the day of the year (expressed in Julian Days, where January $1^{st} = 1$), the second is the time of day based on a 24 hour clock and the third is the PPFD recorded at that time. The day of the year and the time are expected to be in ***local standard time***. This data is used to calculate diffuse and direct PPFD. The user will be prompted to fill in any missing values (see **Load PPFD Values**, page 60). An example of this file can be found in **Appendix A - Open Sky PPFD File (*.pfd)**, page 91.

Any modifications made to the PPFD values within this section of the program can be output as a modified .pfd file.

Tree Stand Files (*.tsd)

The tree stand file is generated by this program and contains the stand description, including a tree list (stem file) and a three dimensional canopy structure similar in design to a LA file.

System Configuration File (ppfd.ini)

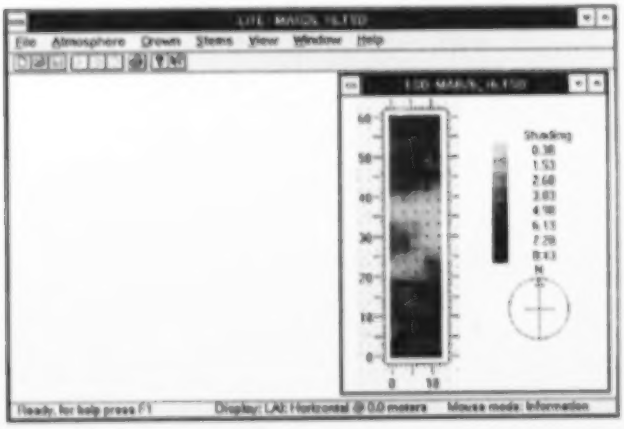
The system configuration file contains system information, including leaf area constants and projection coefficients for each species. This file is intended for machine interpretation only. Users are discouraged from altering this file directly. It is maintained automatically by the program.

5.1.3 Output Files

The files which can be exported are described in the section **5.4.2 Calculation of Exported** Values on Page 85.

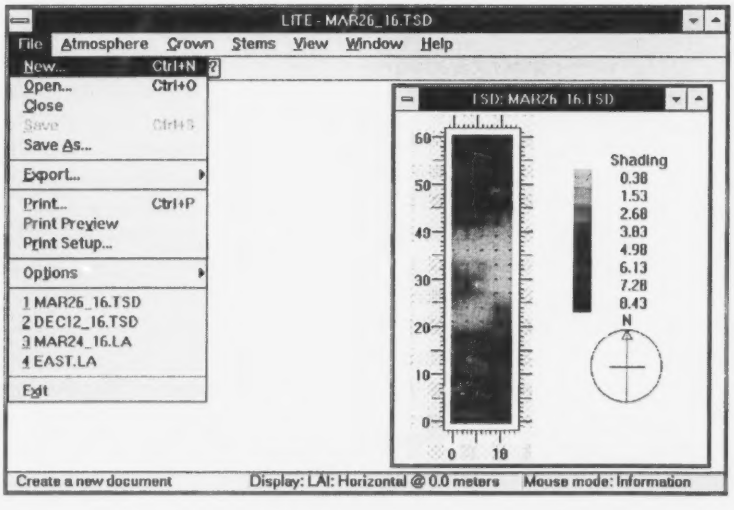
5.2 Tree Stand Modelling Main Menu

The *TREE STAND MODELLING MAIN MENU* consists of seven choices for user interaction: **File, Atmosphere, Crown, Stems, View, Window** and **Help.** The **File** menu controls data input and output from the program. The **Atmosphere** menu allows the user to inspect and modify the global location of the plot as well as the environmental conditions. The **Crown** menu controls crown data input and output. The **Stems** menu controls tree list data input and output. The **View** menu allows the user to view different displays and to select how the display will be presented. The **Window** menu presents users with standard **MDI** options to control windows created by the program. The **Help** menu displays information about the program and supports the user with on-line help.



5.2.1 File Menu

This menu allows the user to perform standard Windows™ file operations on tree stand (TSD) files. **New** allows TSD files to be created. **Open** opens an existing TSD file. **Close** closes an open TSD file. **Save** and **Save As** allow users to save open TSD files without closing them. **Export** takes data from an open TSD file and places it in an ASCII file. **Print** prints the current file, **Print Preview** allows users to check the output before it is printed, and **Print Setup** allows users to set printer options for subsequent print jobs. The **Options** menu item opens up another menu of choices which allow users to set program options which define the way LITE will operate. **Exit** will exit the program. The bottom section of this menu shows the last four files (LA or TSD) which were opened or saved.

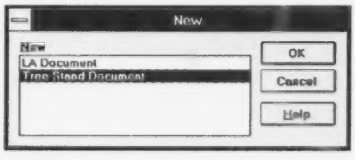


New

There are two file-types that can be created: Leaf Area (LA) or Tree Stand (TSD). The user is first prompted with the type of document to be created. Next, the user is prompted to provide the name of an observation point map file (see **Observation Point Map File (*.map)** on page 17). The new file is named "untitled". Some grayed-out menu items become available after a file is created or loaded.

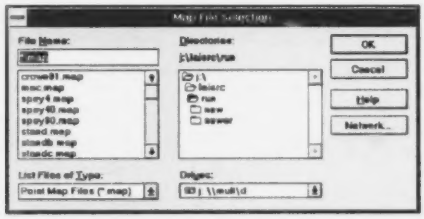
Document Type Prompt

This dialog box prompts the user for the type of document to create. Currently, the user may create either a new LA document or a new TSD document.

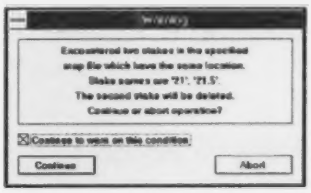


Observation Point Map File Prompt

This dialog box prompts the user for the name of the observation point map data. The observation point data is read from the file and interpreted. See the section **Observation Point Map File (*.map)** on page 17 for specifications and information on these files. The appearance of the dialog box used to input the filename will vary depending on the version and configuration of Windows™. If there are any errors on input, the user is notified by a pop-up dialog box.



If the warning option "Report when a duplicate stake in a map file is found" is enabled and the program encounters two stakes with the same location, a warning box will appear on the screen informing the user of this condition and prompting them to either continue (deleting the second stake) or abort the operation.



Open

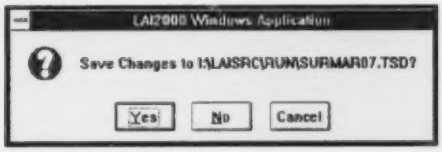
Inputs an existing TSD or LA file. The file is loaded into the program and displayed on the screen in a new window. The user can begin operations on the loaded file. Previously loaded files are unaffected by this action. The dialog box that appears will be very similar to the one used to input the map file name (page 45) but will default to files with an extension of `tsd` or `la`.

Close

The current TSD file is closed and its window in the program is removed. If the file has changed since it was last saved, the user is prompted to save the changes or discard them.

Save Changes on Close Prompt

If any changes were made to the TSD file, the user is prompted to save or discard the changes made. The **No** button does not save any changes made since the last time the file was saved. The **Yes** button on the panel saves the changes to the current file name. The **Cancel** button will remove the message box from the screen and cancel the ***Close*** request.

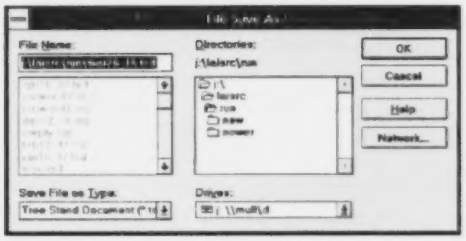


Save

The current TSD file is saved to the disk. If it is a newly-created TSD file, the program will pop up the ***Save As*** dialog box, and the user is prompted for a new file name.

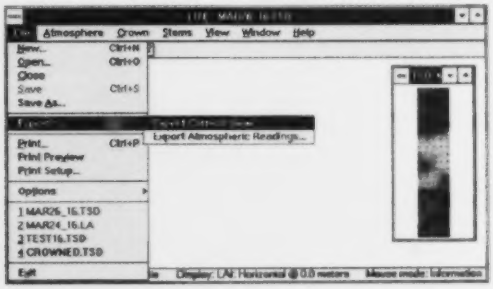
Save As

The current TSD file is saved to the disk. The user is prompted for the name of the file. The current file name is supplied as a default. The user can override the default and save the data in a different file.



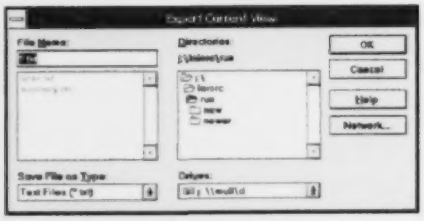
Export

Allows users to export either the current view (**Export Current View**) or above and below canopy readings (**Export Atmospheric Readings**).



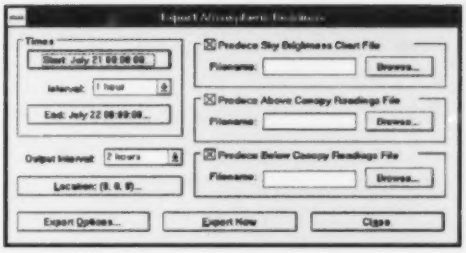
Export Current View

Creates an output (text) file with values (LA, LAI, PPFD, % PPFD Transmittance, etc.) culled from the current view. Upon selecting this menu item, a file save dialog will appear, prompting the user for the name and location of the text file to be exported. Formatting of the export file is explained in **5.4.2 Calculation of Exported** Values on page 85.



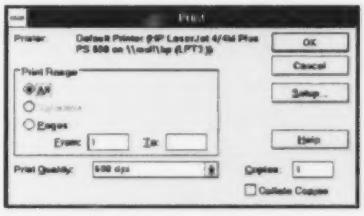
Export Atmospheric Readings

Various above and below canopy PPFD readings can be exported. The user may specify the duration (**Start, End**) and accuracy (**Interval**) of calculations, as well as how often values will be exported to the appropriate files (**Output Interval**). For below canopy readings, the user must also specify the point at which such readings are calculated (**Location**). If the **Produce Below Canopy Readings File** checkbox is unchecked, the **Location** button will be disabled. A file name must be specified for each output type requested, otherwise an error message will occur. If the user presses the browse button, a dialog box similar to the **Export Current View** box (above) appears, prompting the user for a filename which, after the user presses OK, is inserted into the appropriate **Filename** box. Alternately, the user can simply type a valid filename directly into the **Filename** box.



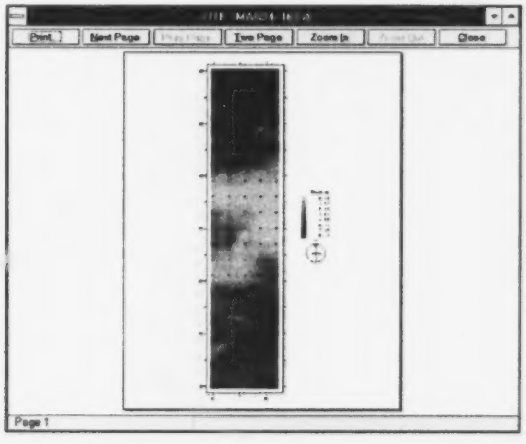
Print

The default printer is displayed and the user is prompted to select the print range and quality. This is a standard dialog box in the Windows™ environment.



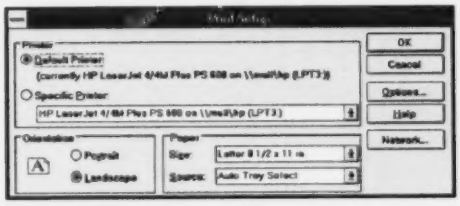
Print Preview

Displays the current page as it will appear when printed. This is a standard tool in the Windows™ environment.



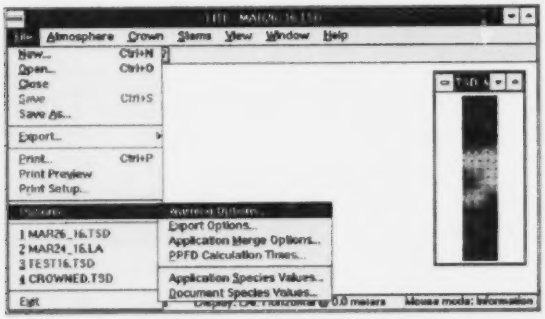
Print Setup

This dialog box prompts the user to choose a printer and provides paper orientation and size options. It is a standard dialog box in the Windows™ environment.



Options

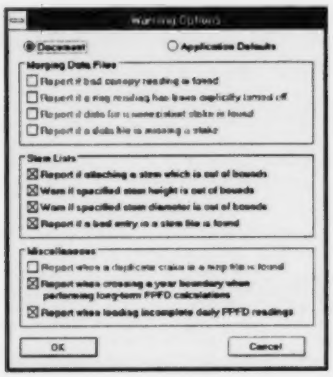
The Options menu item controls optional behaviour of the program such as warning about input conditions, the default behaviour of tree species, and other behaviours. They are detailed below.



Warning Options

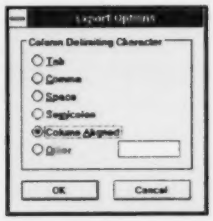
The program can report warnings for erroneous input conditions that may arise when working with TSD files. The user can choose to have these conditions reported or not. The application defaults are stored in the program's initialization file. The disabled options in the panel do not apply to this part of the program.

The **Document** and **Application Defaults** buttons permit the user to store the state of these options. When the Application Defaults button is selected, the state of the input warnings are saved to the initialization file and will be used for data added to any other stands. When the Document button is selected, changes to the Warning Options are not kept. The input warnings are applied only to the current stand.


Warning Options
Document
Application Defaults
Merging Data Files
Stem Lists
Report if attaching a stem which is out of bounds
Warn if specified stem height is out of bounds
Warn if specified stem diameter is out of bounds
Report if a bad entry in a stem file is found
Miscellaneous
Report when crossing a year boundary when performing long-term PPFD calculations
Report when loading incomplete daily PPFD readings
OK
Cancel

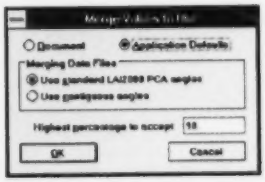
Export Options

The user can export various types of data, as described in the TSD portion of this document. The options in this dialog box specify the formatting of the export files. Either a special character can be used to separate columns of data (e.g., a comma), or the user can choose to align the columns.



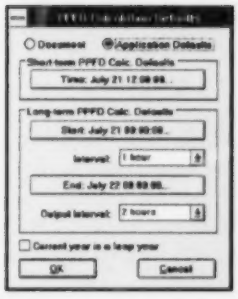
Application Merge Options

The standard LAI2000 PCA angles have slight gaps between the rings. The user has the option of using either the LAI2000 PCA angle specification or LITE's angle specification (which eliminates the gaps) when the .DAT files are merged. The **highest percentage to accept** value specifies the break-over point at which the associated leaf area is deemed to be so minimal that it should be eliminated. This value is used to mark the area of the crown space as having no leaf area in an effort to more accurately represent the original crown space of the stand by affecting the distribution of information in the .DAT files. The **Document** button is disabled in this dialog, because only LA files are affected by the options chosen here, however application-wide defaults can be set.



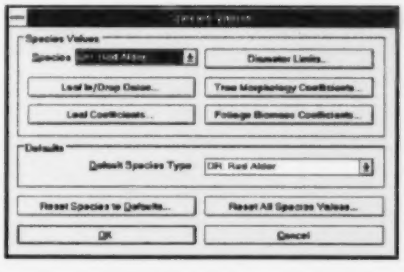
PPFD Calculations

This dialog lets the user specify the initial times and accuracy for PPFD calculations when documents are initially created or re-opened. If a TSD document is open, the user can choose between document and application defaults. The "Short-term PPFD Calc. Defaults" button allows users to specify the default time used for instantaneous calculations. The "Long-term PPFD Calc. Defaults" section allows users to specify the start and end dates for long-term calculations, along with a time interval for both the calculations and output of those calculations. If **Current year is a leap year** is checked, PPFD calculations (after February 27th) will be adjusted to take the extra day into account. For example, if the user checked the box below, the short-term time would be adjusted to read July 20 and the long-term interval would be adjusted to start on July 20 and end July 21 and all PPFD calculations would be adjusted accordingly. This option can be set at both the document and at the application level.



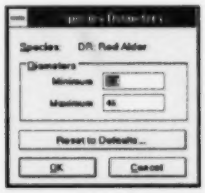
Application/Document Species Values

Users have the ability to alter the default species coefficients at the application level. When a new document is created, it inherits the species coefficients from the application. Users who wish to change the species coefficients for all new documents should change these values using the **Application Species Values** menu option. Users who wish to change the species coefficients for a single document should use the **Document Species Values** menu option. The sequence of dialog boxes and options are the same for both the **Application Species Values** and the **Document Species Values** and are shown below. Each species has its own set of values, and may have different dialog boxes to support different formulas. When this dialog is first opened, there is no species in the **Species** box, and the associated buttons are disabled.



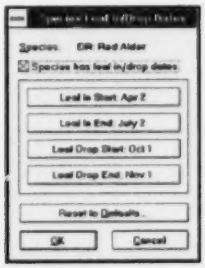
Diameter Limits

This dialog box allows the user to select a minimum and maximum diameter limit for stems. These values are used to validate stem diameters when they are imported from a file.

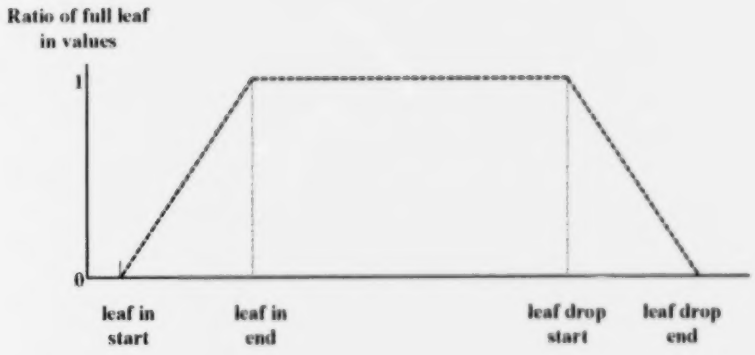


Leaf In/Drop Dates

Users can specify the leaf in and leaf drop behaviour for each species in their area. The program assumes that there are no leaves before the **Leaf In Start** date and no leaves after **Leaf Drop End** date. Between the **Leaf In End** and **Leaf Drop Start** dates, the program assumes that all leaves are fully developed. Between the start and end dates for Leaf In and Leaf Drop, the program uses linear interpolation to calculate leaf areas. If **Species has leaf in/drop dates** is unchecked, that particular species will have a constant canopy year-round and the buttons to change the leaf in/drop dates will be disabled.

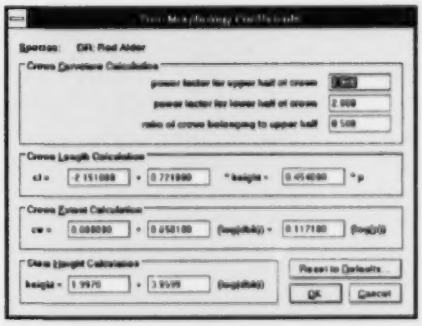


The following graph illustrates the methodology used. Before *leaf in start*, there are no leaves (the ratio of full leaf in values is 0). Between *leaf in start* and *leaf in end*, the program calculates the ratio as a value increasing from 0 to 1. Between *leaf in end* and *leaf drop start*, the leaves are fully developed (the ratio of full leaf in values is 1). Between *leaf drop start* and *leaf drop end*, the program calculates the ratio as a value decreasing from 1 to 0. And after *leaf drop end*, there are again no leaves.



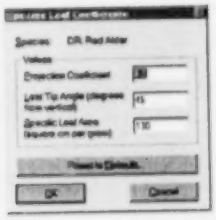
Tree Morphology Coefficients

These coefficients are used to determine the dimensions of the crown of each species of tree. Depending on how much data the user has provided for each stem, the values specified in this dialog box may not be used for all stems. For example, the crown extent for each quadrant can be specified by the user. If the user has specified crown extent values, they will be used in place of the formula and coefficients specified in this dialog box. The **Crown Curvature Calculation** section allows the user to define the actual shape of the crown. The **power factor for upper half of crown** refers to the shape of the upper half of the crown, **power factor for lower half of crown** refers to the shape of the lower half, and **ratio of crown belonging to upper half** defines the boundary for the upper and lower halves of the crown. For more information on how these values affect crown shape, see **5.4.3 Crown Generation, page 87**. In the following example, "cl" stands for crown length, "ce" for crown extent, "height" for stem height, "dbh" for diameter at breast-height, "p" for the distance to the closest tree in the specified quadrant, and "log" to natural logarithms.



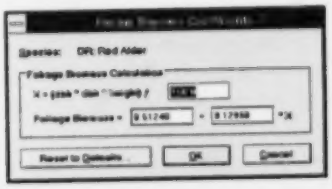
Leaf Coefficients

These values are used by different formulas in the program. The **Projection Coefficient** is used to determine how much light is intercepted by the leaves of the given species. The **Leaf Tip Angle** is used to determine the vertical projection of leaf area and the **Specific Leaf Area** is used to convert foliage biomass to leaf area.



Foliage Biomass Coefficients

These coefficients are used to determine the amount of leaf area associated with stems during crown generation, which takes place in the TSD portion of LITE. As different equations are required for different species, different dialog boxes will appear depending on which species has been selected. The following shows the dialog box used for Red Alder, where "dbh" is the diameter at breast-height and "height" is the current height of the tree.

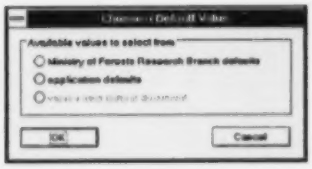


Default Species Type

Any area in a TSD document which is not associated with a tree uses the default species information for PPFD calculations. This allows PPFD to be calculated even when the canopy is only partially (or not at all) associated with trees.

Reset Species to Default

The users have the ability to quickly change species values back to a default state, allowing users to correct mistakes or to apply values for a specific region, tested in one document, to the application default values. A choice is given among **Ministry of Forests Research Branch defaults** (which cannot be modified), **application defaults** (which are saved in LITE's INI file), or **values from the current document** (this option is only enabled if a valid TSD document is currently open).



Reset All Species Values

This option allows the user to reset all of the species values to a default. Whereas 'Reset Species to Default' changes all of the values associated with one species, this option will change all the values of all the species to the set of defaults selected by the user. The dialog box used for this option is identical to that used for the "Reset Species to a Default" option (above).

File List

The four most recently opened or saved files are listed. The user may open one of these files by selecting it.

Exit

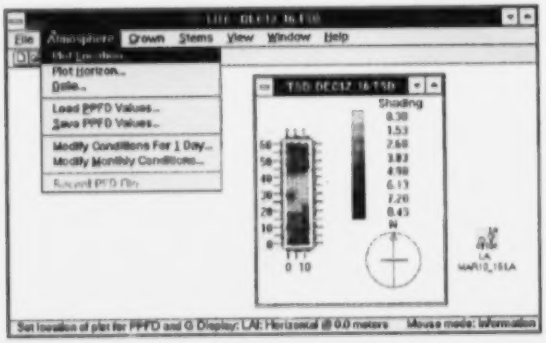
The program exits to the Windows™ environment. The program checks all open TSD and LA files for changes, and prompts the user to save or discard changes before exiting.

Save Changes on Exit Prompt

The user is prompted to save or discard the changes made to the TSD or LA file. The dialog box that appears is similar to the one that is used for the ***Save Changes Prompt*** for the ***Close*** menu option above. The **Cancel** button will remove the ***Save Changes Prompt*** dialog box from the screen and cancel the ***Exit*** request.

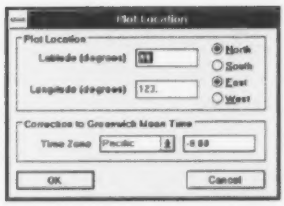
5.2.2 Atmosphere Menu

This menu allows users to inspect and modify conditions which relate to location and environment. **Plot Location** allows the specification of global location for the plot. **Plot Horizon** enables the modification of the horizon from its default position. **Date** allows users to specify the date used for calculations. **Load PPFD Values** reads in yearly plot data from an ASCII file, and **Save PPFD Values** saves plot data to an ASCII File. **Modify Conditions for 1 Day** and **Modify Monthly Conditions** allows users to edit environmental conditions. The bottom section of this menu shows the last four PPFD files which were loaded or saved.



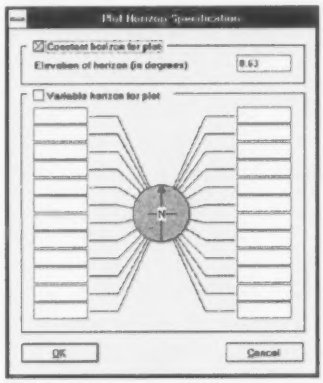
Plot Location

This dialog allows the user to specify the geographic location and time zone of the plot. This data is used for tracking the location of the sun in the sky, and adjusting local time information that is input from other sources. These values are saved with the TSD file and, as a rule, do not need to be entered more than once. The user can enter any valid **Latitude** (either **North** or **South**, and ranging from 0 to 90 degrees) or **Longitude** (either **East** or **West**, and ranging from 0 to 180 degrees). The **Time Zone** can be entered either as one of named time zones (Alaska, Pacific, Mountain, Central, Eastern, or Atlantic) for North America or by entering an adjustment factor to Greenwich Mean Time (GMT). When the user selects a named time zone, the program displays the associated time adjustment factor. If the user enters an adjustment factor, it must be entered according to the standard Windows™ time format (hours:minutes:seconds).



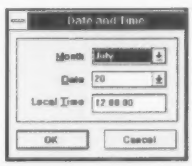
Plot Horizon

This dialog allows users to create a variable horizon. The default is 8.63° off horizontal (the effect of which is to eliminate the bottom three sets of cells). However, the user may wish to enter different numbers, for example, to model a mountain or cliff. The user can click **Constant horizon for plot** and enter a constant value for **Elevation of horizon** or click **Variable horizon for plot** and enter a separate value for each of the 24 divisions of azimuth. Note: the orientation of the 24 divisions (to North) will coincide with the orientation of the plot itself (as indicated by the compass heading at the centre of the dialog).



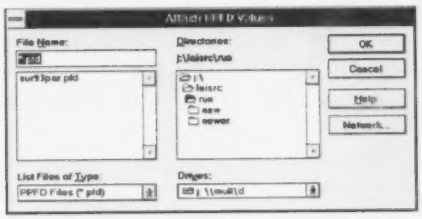
Date

This option allows the user to specify the local date and time used to calculate instantaneous PPFD values. Time must be entered in standard Windows™ time format (hours:minutes:seconds).

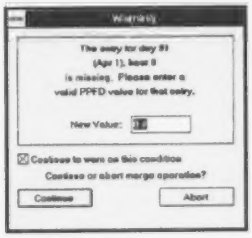


Load PPFD Values

This option loads hourly open sky PPFD readings for up to one full year taken from a weather station. The file format is described in the section **Open Sky PPFD File (*.pfd)** on Page 42. These values are used to determine the overcast condition and partition available light into direct and diffuse sources. The open sky PPFD values are subsequently stored in the current TSD file. They are saved with and restored from the TSD file and, as such, are normally only entered once.



If any values are missing from the PPFD file, a warning box will appear provided that option has not been disabled on the Warnings menu.



The default replacement value is zero. If the user changes the number (in the **New Value** box), the new number is used as a default for the rest of the missing values. If the user unchecks the option **Continue to warn on this condition**, the warning box is closed, and the current default is used for the remainder of missing values. If the user has disabled the warning box in the Warnings menu, zero will be used for all missing values. The default value in the **New Value** box is reset to zero, and the option to continue to warn users is turned on each time this operation is performed.

Save PPFD Values

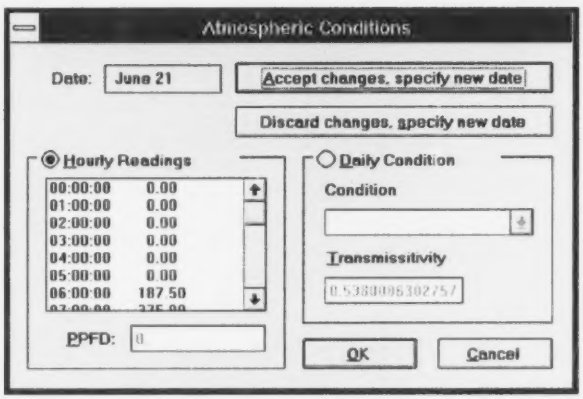
This option saves current hourly open sky PPFD readings to an Open Sky PPFD file in the file format described in the section **Open Sky PPFD File (*.pfd)** on Page 42.

Modify Conditions for 1 Day

The user may at any time inspect and modify the open sky light conditions for a particular day. This dialog box has two modes, **Hourly Readings** and **Daily Condition**. To select the mode by which the weather conditions will be stored, the corresponding button must be clicked.

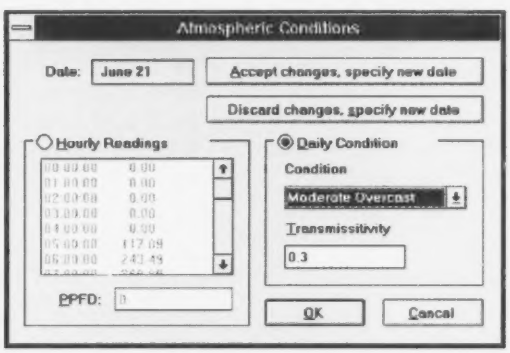
Hourly Readings Mode

In this mode, the weather conditions for the date specified in the date-field (June 21st, in this example) are specified using hourly readings given in local time. The corresponding daily transmissitivity value is calculated from the noon local standard time reading. Selecting a particular list entry (hour) and modifying the corresponding value (for that hour) in the PPFD edit-field allows the user to modify any hourly reading. In this mode, the user cannot directly enter a daily condition or transmissitivity value.

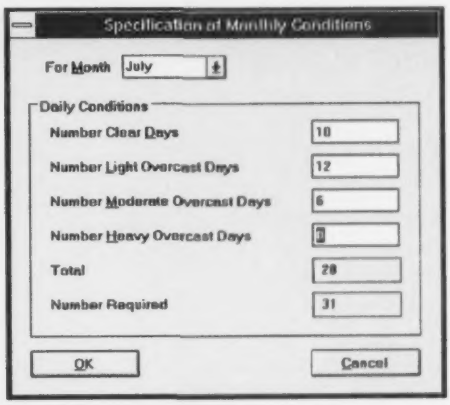


Daily Condition Mode

In this mode, daily weather conditions are set by specifying the transmissitivity. Some daily conditions are pre-set, but the user has the option of directly specifying the transmissitivity. The hourly readings, which cannot be directly edited, will be calculated from the transmissitivity value specified.



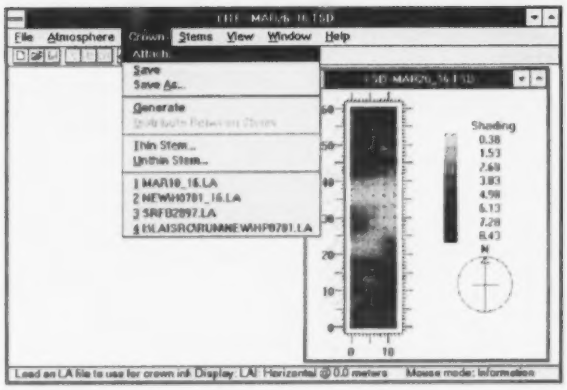
Modify Monthly Conditions
This option allows the user to specify daily transmissitivity conditions for an entire month. The user must specify the number of days for each weather condition, so that total days is equal to the number of days in the selected month. In this example, the program will set daily conditions to "clear" for 10 days in July.



Atmosphere Conditions File List
The four most recently loaded Open Sky PPFD files (*.pfd) are listed. The user may attach one of these files by simply selecting it.

5.2.3 Crown Menu

This menu controls crown data input and output. **Attach** opens a file (LA or TSD) and attaches its crown to a TSD file. **Save** and **Save As** save the current canopy as an LA file. **Generate** generates crowns in the crown space, using the current tree list. **Distribute Between Stems** distributes the crown space among the existing stems. **Thin Stem** sets the mouse to selectively thin the stems of a TSD file and **Unthin Stems** turns this option off. The bottom section of this menu shows the last four files (LA or TSD) that were attached or saved.

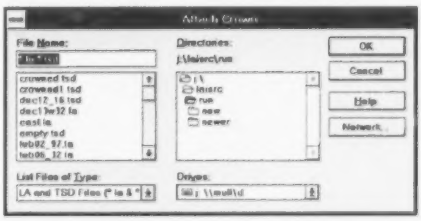


Attach

Opens an LA or TSD file and attaches its crown to the current TSD file. The LA file becomes the new canopy of the stand. Any existing canopy is discarded, regardless of whether the existing canopy was attached or generated. If there is a stem list in the TSD file, the canopy can be automatically distributed among the stems using the method described in the section **Distribute Between Stems** on Page 64. The new crown must have been created with the same map file as the original in order for the operation to be carried out.

Crown Attach File Prompt

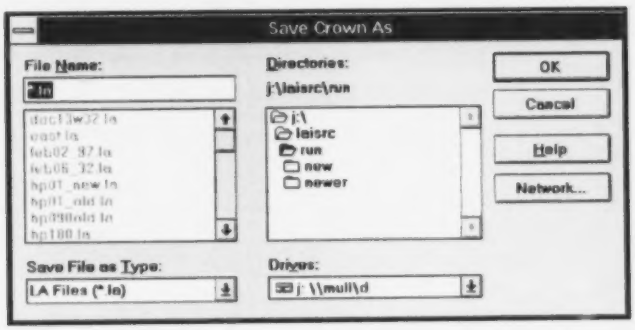
This dialog box prompts the user for the name of the file containing the canopy. The data is read from the LA file and interpreted. If there are any errors, the user is notified by a pop-up dialog box. The appearance of the dialog box used to input the file name will vary from system to system depending on the version and configuration of Windows™ in use.



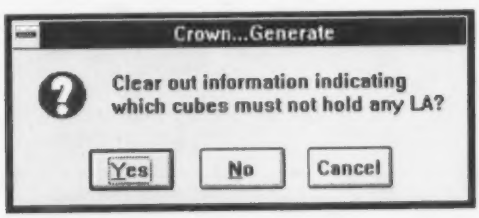
Save

The current canopy is saved as an LA file to the disk. If it is a newly created file, the program will pop up the ***Save As*** dialog box, and the user will be prompted for a new file name.

Save As
The current crown file is saved to the disk. The user is prompted for the name of the file. The current file name is supplied as a default. The user can override the default and save the data in a different file.



Generate
The current tree list is used to generate crowns in the crown space. The tree parameters are used to create crowns specific to each tree based on its size, species, neighbors, etc. This replaces the current crowns regardless of whether they were generated or attached. When the user chooses this option, a message box will appear allowing the option of clearing any information previously calculated which flagged certain cubes (sections of the stand canopy) as unable to contain LA.



At the point where LA files are merged, calculations are done to determine which cubes should not contain LA. This option allows the user to discard those calculations and enable those particular cubes to contain LA when the crowns are generated. Note: this message box will appear regardless of whether or not any cubes have been flagged. If the current stand contains no stems, this menu item will be disabled.

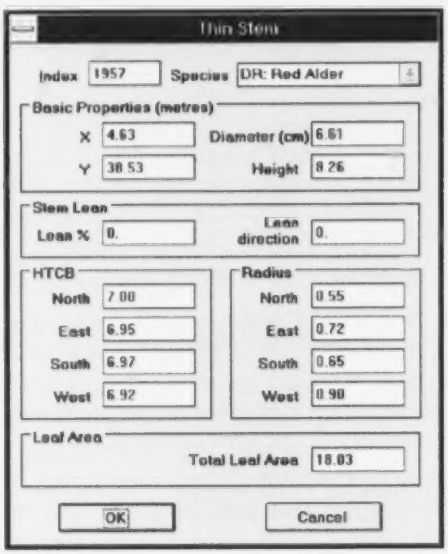
Distribute Between Stems
The crown space is distributed amongst the existing stems. If no stems were created or attached, then this menu item is disabled. The program uses a Delauney tesselation to partition the crown space into Voronoi regions around each stem.

Thin Stem

This menu item sets the mouse mode to selectively thin stems which belong to the file. When this mode is selected, the status bar will reflect this and the menu item will be checked. When the user selects a stem (a point on the map), a ***Thin Stem*** dialog box will appear to confirm the user's action. Thinning an existing stem does not remove it, but marks the crown associated with the stem as non-existent. This is not a destructive operation, as the stem can be unthinned, restoring its crown to its previous values. This option will stay in place until the user "de-selects" the menu option, causing the check mark to disappear.

Thin Stem Dialog

If the ***Thin stem*** option has been activated, when the user selects a point on the map by clicking on it, this dialog appears, with information about that particular stem. The user has the option of thinning the stem by pressing the **OK** button or selecting another stem by editing the **Index** field. All other options are disabled.



Unthin Stem

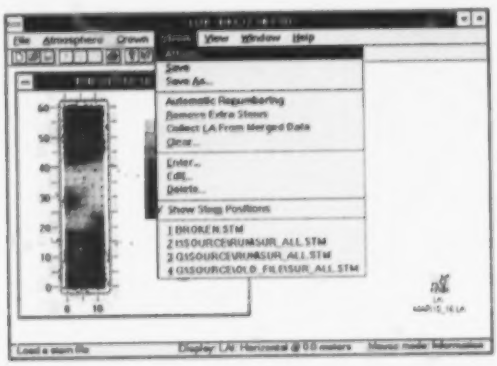
This menu option sets the mouse mode to reverse the operation of the ***Thin Stem*** option. It similarly to the ***Thin Stem*** dialog box (above) when the user selects a point on the map.

Crown File List

The four most recently attached or saved crown as LA files are listed. The user may attach one of these files by selecting it.

5.2.4 Stems Menu

This menu controls the input and output of tree list data. **Attach** loads an ASCII stem list file. **Save** and **Save As** saves the current stem list to an ASCII file. **Automatic Renumbering** renumbers the stem list consecutively. **Remove Extra Stems** removes extraneous stems. **Collect LA from Merged Data** uses the data to calculate the leaf area for the stems (as opposed to pre-defined equations). **Clear** removes all of the stems from the current tree stand file. **Enter**, **Edit** and **Delete** allow for the input, removal and modification of individual tree data. **Show Stem Positions** draws the stem map on the display of the current stand map. The bottom section of this menu shows the last four stem list files (STM) that were attached or saved.

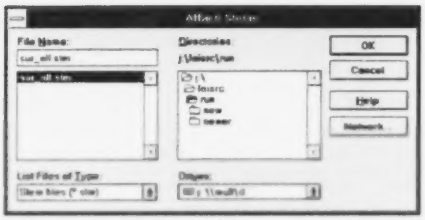


Attach

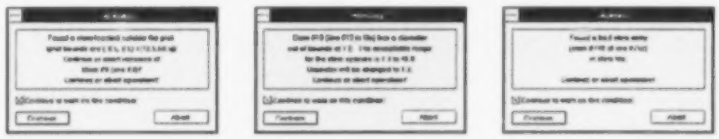
Loads an existing stem list file. The loaded stem list replaces any current stem list. The existing crown is divided amongst the stems using the generated Voronoi tesselation. Where crowns belonging to either LA or TSD files can be attached, stem lists must be loaded from stem files only. All stems previously associated with the TSD file will be deleted before this operation begins.

Stem Attach File Prompt

This dialog box prompts the user for the name of the stem list. The stem list data is read from the file and interpreted. The appearance of the dialog box used to input the file name will vary depending on the version and configuration of Windows™.



The following error messages may occur when a stem list is merged. The user can choose to continue or abort the "attach stems" operation, and choose whether to be notified of any other errors of this type.



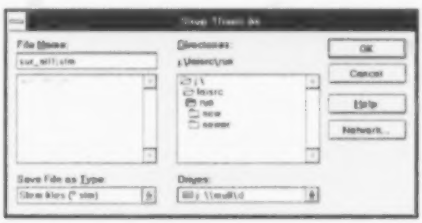
Once stems have been attached, the program will prompt the user to remove any stems which have no impact on the plot. The program then decides which stems have no impact on the plot based on the Voronoi regions associated with each of the stems. If the Voronoi region of a stem does not overlap with the area defined by the bounding rectangle of the map file associated with this TSD, the stem will be removed.

Save

The current stem list file is saved to the disk. If it is a newly created stem list file, the program will pop-up the ***Save As*** dialog box, and the user will be prompted for a new file name.

Save As

The current stem list is saved to the disk. The user is prompted for the name of the file. The current file name is supplied as a default. The user can override the default and save the data in a different file.



Automatic Renumbering

Selecting this option causes the list of stems to be renumbered consecutively to account for gaps in the numbers given to stems, which may occur when invalid stem are discovered on input or when stems are deleted from the list.

Remove Extra Stems

Removes any stems which do not impact on the defined crown space (i.e., those that are beyond the TSD plot area).

Collect LA from Merged Data

Instead of using pre-defined equations to calculate the leaf area for the stems in a TSD, the program collects the leaf areas associated with each stem by adding up each cubic metre associated with that stem.
Once crowns have been generated (from the Crown menu), this item is disabled, as the program no longer has access to the merged data.

Clear

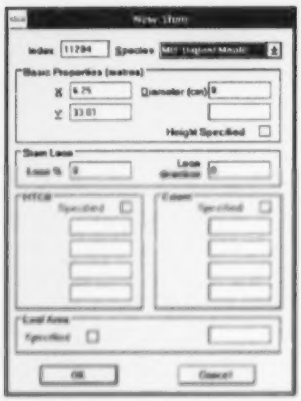
Removes all of the stems from the current tree stand file. This allows the user to remove all existing stems in preparation for manual stem entry.

Entering, Deleting and Editing Individual Stems

The user may input, remove or modify data for individual trees in the dataset. Selecting **Enter, Delete** or **Edit** causes a check mark to appear on the menu beside the mode selected and the program to enter into the selected mode. The modes are mutually exclusive, so only one may be selected at a time. Clicking in the active window causes a dialog box to appear to perform the commands listed below. The program stays in that mode until the check-mark is removed. To remove the check mark, either select the command again or select a different mode.

Enter

In this mode, the user can enter the properties of a new stem to be added to the tree list. The **Index** field is a user-specified name for a given stem. If the **Height Specified** box is unchecked, values cannot be entered in the **HTCB, Extent**, and **Leaf Area** fields. If the **Extent Specified** box is unchecked, values cannot be entered in the **Extent** or **Leaf Area** fields. If the **Leaf Area Specified** box is unchecked, values cannot be entered in the **Total Leaf Area** field. Any values not explicitly specified by the user will be calculated by the program.



Edit

A dialog box similar to the ***Enter*** dialog box will appear. In this mode, the user can change one or more of an existing stem's properties. By changing the **Index** field, the user can modify a different stem, however, any changes made to the previous stem will be lost. If no stems exist, a message box will pop up advising the user of this. If stems are visible, the selected stem will be highlighted in yellow. The check-boxes within this dialog box and the fields they enable are the same as those in the ***Enter*** box.

When editing stems which have had their leaf area determined using the Collect LA from Merged Data method (see page 68), the program will revert back to using a pre-defined equation to calculate the leaf area if the Leaf Area Specified box has been checked (allowing users to modify the leaf area), and then subsequently unchecked.

Delete

A dialog box similar to the ***Enter*** dialog box above will appear. In this mode, the user can remove a stem from the tree list. If no stems exist, a box will pop up advising the user of this. Only the **Index** field can be changed in order to specify the correct stem to delete. If stems are visible, the selected stem will be highlighted in yellow on the display of the current stand map.

Show Stem Positions

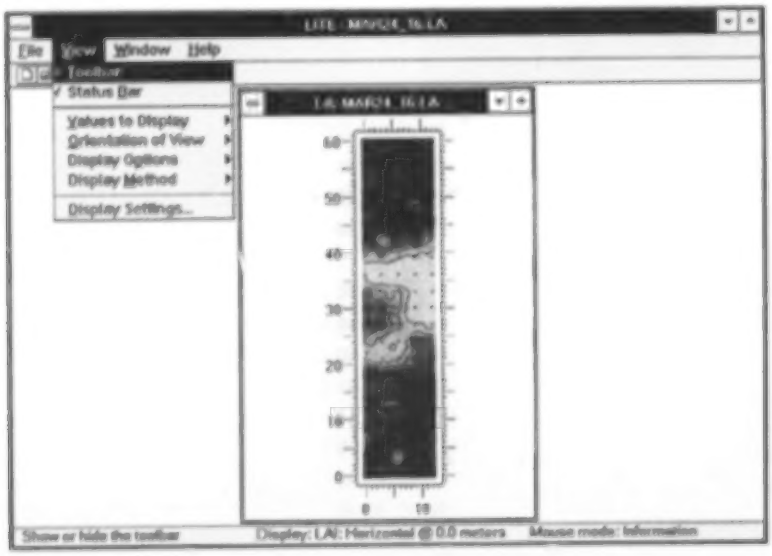
Draws the stem map on the display of the current stand map. A brown circle will appear on the stand map at the location of each stem in the stand. The stem map will always appear on top of any other objects the user has requested.

Stem File List

The four most recently attached or saved stem files are listed. The user may open one of these files by selecting it.

5.2.5 View Menu

The options on this menu allow users to change the look of the display. Selecting **Toolbar** or **Status Bar** causes a check mark to appear beside the option on the menu. These options can be selected at the same time, allowing the user to display both on the screen. **Values to Display** changes what data is displayed in the current window. **Orientation of View** changes what part of the data is displayed in the current window. These menu items are mutually exclusive within their section (only one view and one type of data may be seen in a window at a time). **Display Options** annotates the display of the current window. **Display Method** controls how the data is displayed. None, one, or many of these options can be selected at a time. **Display Settings** gives the user a centralized location (a single dialog box) from which to modify all the view-options at once.



Toolbar
Selecting this item from the menu will toggle the toolbar on the main window. The toolbar, a group of buttons located directly under the main menu, can be used for quick access to commonly used commands if the user has a pointing device such as a mouse or Glidepoint™.

Status Bar
Selecting this item from the menu will toggle the status bar. The status bar, located at the bottom of the main window, provides information about the active document or highlighted command and also shows the state of the **CapsLock**, **NumLock** and **ScrollLock** keys.

Values to Display
Selecting this menu item brings up a list of options from which the user can

specify the data to be displayed. Only one option, which will have a check mark beside it, can be selected at a time.

LA (Leaf Area)

Draws a map of **LA** on the screen. The **LA** is calculated for each square meter of the current view and is displayed in the current window. The **LA** view is a one metre thick horizontal or vertical slice of the canopy.

LAI (Leaf Area Index)

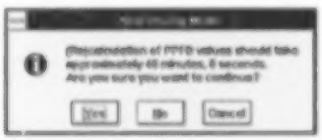
Draws a map of **LAI** on the screen. The **LAI** is calculated for each square meter of the current view and is displayed in the current window. **LAI** is defined as the sum of the **LA** *above* the current display elevation.

 # Measurements per Cube

The number of measurements or observations that were used to determine the **LA** of each cube is displayed in the current window. This option displays values for a one metre thick horizontal or vertical slice of the canopy.

PPFD (Photosynthetic Photon Flux Density)

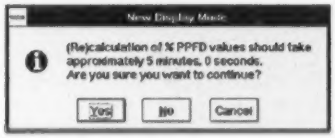
Draws a PPFD map on the screen based on the user's current perspective selection. The PPFD map shows the amount of instantaneous PPFD penetrating to the centre of each cubic metre of the user's canopy. In general, this is a time consuming computation and may take a long time to complete. As a rule, it is not an interactive activity and can take anywhere from several minutes to hours to complete. Very large plots on slower computers may take more time to compute than most users are willing to wait. Because of the time involved, the program will pop up a message box with an approximation of the time it will take to complete the operation. This is an approximation based on timing the calculations of three sample points and using this as a base-line to estimate the time required to complete the calculations for all points in the canopy.



% PPFD Transmittance

Draws a map of % transmittance on the screen based on the user's current perspective selection. This map shows the percentage of open sky PPFD penetrating to the centre of each cubic metre of the user's canopy. This is a non-interactive, time-consuming computation, and can take anywhere from several minutes to hours to complete. Very large plots on slower computers may take more time to compute than most users are willing to wait. Because of the time involved, the program will pop up a message box with an approximation of the time it will take to complete the operation. This is an approximation based on timing the calculations of three sample points and

using this as a base-line to estimate the time required to complete the calculations for all points in the canopy.

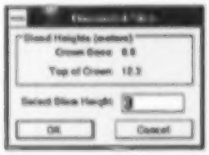

(Re)calculation of % PPFD values should take approximately 5 minutes, 0 seconds.
Are you sure you want to continue?
Yes
No
Cancel

Orientation of View

Selecting this menu item brings up a list of options, from which the user can choose a particular "orientation" (horizontal or vertical) for the data. Only one option, which will have a check mark beside it, can be selected at a time.

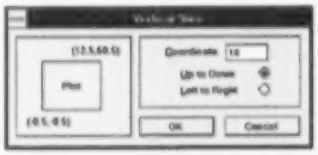
Horizontal View

This choice will draw a map of a plane parallel to the earth's surface intersecting the canopy. The user is prompted to select the height of the view above the ground in metres. The maximum and minimum crown heights are displayed in the dialog box to assist the user in making their selection. The program then displays the data values (LAI, LA or # of measurements) of the layer of cubes that are the selected distance above the ground.



Vertical View

This choice will draw a map of a plane perpendicular to the earth's surface intersecting the canopy. The plane must be parallel to one of the user's axes. The user is prompted to select either **Up to Down** (parallel to the Y-axis) or the **Left to Right** (parallel to the X-axis), and the **Coordinate** (distance from the origin) of the view in metres. The plot boundaries are displayed in the dialog box to assist the user in making their selection. The program displays the data values of the wall of cubes that are the selected distance from the origin of the plot.



Display Options

Selecting this menu item brings up a list of options from which the user can choose various elements to display as part of the output. Any options which were selected will have a check mark displayed beside them on the menu. If the user subsequently deselects an option, the check mark associated with that option will be erased. More than one option can be selected at a time, allowing the user to overlay various elements on the screen display, or on the printed output.

Show Stake Positions

Displays the positioning of the observation points read from the **map** file. These are the points at which the canopy heights are measured and the LAI 2000 PCA readings were taken in the stand. Typically, stakes are driven into the ground at these points.

Show Stem Positions

Draws the stem map on the display of the current stand map. A brown circle will appear on the stand map at the location of each stem in the stand. The stem map will always appear on top of any other objects the user has requested.

Show Legend

Displays a shading legend consisting of eight display values (either colours or patterns) and the actual data values used to create the display values. The shading legend is displayed beside the actual display. Although only eight colours are shown on the legend, sixty-four colours are actually used to paint the display map.

Show Ruler

This option will display a border around the display of the plot. The border is annotated with the size of the plot. This is useful when attempting to determine the location of artifacts in the plot or when deciding offsets and distances for views.

Display Method

Selecting this menu item brings up a list from which the user can control how the data is displayed. Any options which have been selected will have a check mark displayed beside them on the menu. If the user subsequently deselects an option, the check mark associated with that option will be erased. More than one option can be selected at a time, allowing the user to overlay colours, patterns, and isolines on the screen display, or on the printed output.

Colour

Shades the map in the current window with colour. Colours do not overwrite patterns nor isolines. Colours will not appear on printed output. Instead, colours will be translated to patterns or grey scales.

Pattern

Uses patterns to shade the current map. Patterns are drawn over colours on the screen but not over the isolines.

Isolines

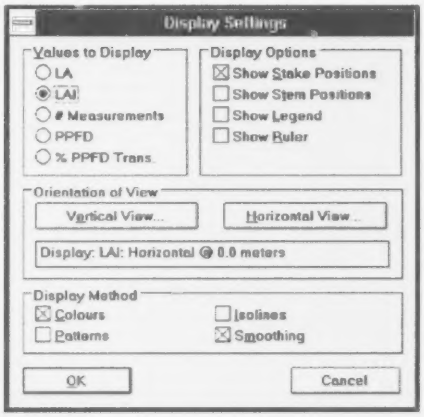
Puts isolines on the current map. Isolines are drawn over any colours or patterns currently on the screen.

Smoothing

If **Colour** has been chosen as a display method, choosing **Smoothing** will blur the boundaries between the different colours, resulting in a much smoother looking output.

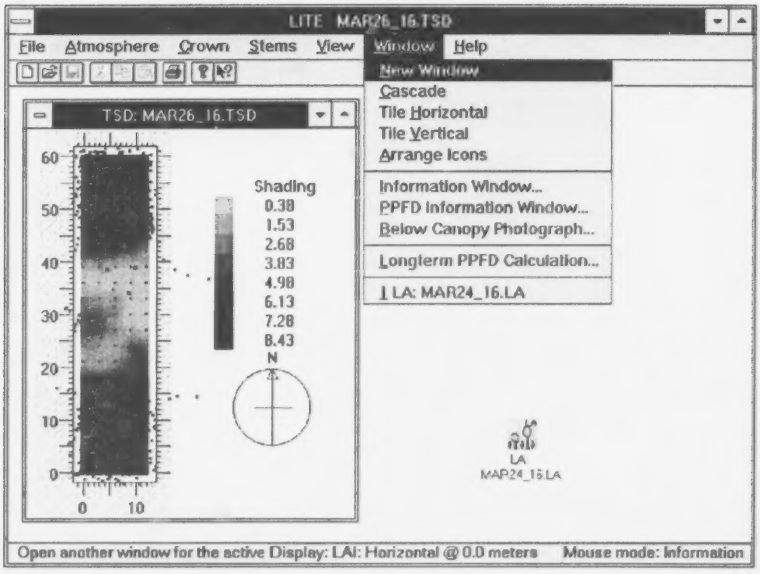
Display Settings

As an alternative to menu toggles, a dialog box is available to make many changes to the display from a centralized location.



5.2.6 Window Menu

The **Window** menu presents users with standard **MDI** options to control windows created by the program. The **New Window** option creates a copy of the selected window. The **Cascade** option arranges all of the open windows from the top left to the bottom right of the main program window. This allows all of the title bars to be easily read. The **Tile Horizontal** and **Tile Vertical** options arrange the open windows as smaller tiled windows in the main program window. These option are useful for seeing a piece of each of the open windows. The **Arrange Icons** option aligns all of the iconic (minimized) windows in a row at the bottom of the main program window. The **Information Window** toggles a window with information about the selected map. The bottom section of this menu shows all of the open files, whether in an open window or in icon form. The user can select the file of choice using the mouse or the keyboard. The selected window is opened (if minimized), brought to the front, and receives the input focus.



New Window

Creates a copy of the current window and gives it the input focus. The user can then select a different view of the same stand. This is the standard Windows tool for allowing a user to create a new view of the same document.

Cascade and Tile Selections

The Cascade selection causes all of the open windows to be cascaded inside the main application window. After windows have been cascaded, their title bars and system menus are visible and accessible, allowing the user to easily find and display a particular one.

The Tile selection causes all of the *open* windows to be tiled either horizontally or vertically inside the main application window. This is useful for displaying two or more windows at their maximum size simultaneously. The user selects the format, vertical or horizontal, that is most appropriate for viewing their data. If the user has more open windows than they wish to tile, they must minimize the excess windows (making them icons) before selecting Tile.

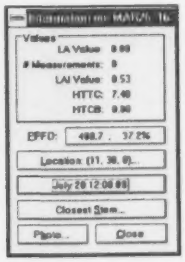
Arrange Icons

This selection causes all of the minimized windows (icons) inside the application window to be arranged neatly along the bottom of the application window.

Information Window

This dialog displays basic instantaneous values for a point on the map. From this dialog, the user may specify a different point and a different time for instantaneous calculations (duration of one second). The user may also examine the closest stem to the specified location. The user also has the

ability to display the below canopy photograph for the specified location. This dialog can also be accessed by clicking directly on a point in the map window.

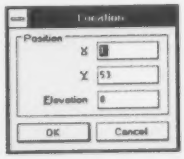


PPFD Information Dialog

This dialog, accessed by pressing the button to the right of the PPFD label on the ***Information*** window, is the same as that of the ***PPFD Information*** window, described below.

Location Dialog

From this dialog, accessed by pressing the **Location** button on the ***Information*** window, information can be entered to pinpoint a specific map location. The user is prompted to enter the **X** and **Y** coordinates (where 0,0 is in the lower, left-hand corner of the map), along with an **elevation**. Any numbers entered which are out of range will be modified to fit the range of valid data.

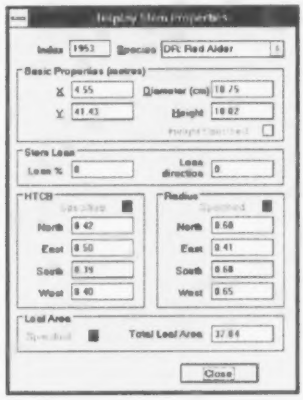


Date and Time Dialog

This option, accessed by pressing the "date" button (the one with a date on it) on the ***Information*** window, allows the user to specify the local date and time used to calculate instantaneous PPFD values. Time must be entered in standard Windows™ time format (hours:minutes:seconds).

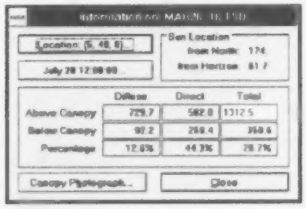
Closest Stem Dialog

This dialog is displayed when the user presses the **Closest Stem** button on the ***Information*** window, and displays the properties of the stem closest to the specified point. No fields can be modified by the user.



PPFD Information Window

The PPFD information window provides more detailed information about PPFD values, including the sun location, as well as the break-down of total PPFD to total above and below canopy PPFD. All PPFD calculations take into consideration parameters such as tree species types and leaf in and drop periods. The beam component is calculated from the exact sun location over the plot. (For long-term calculations, the beam component of the total PPFD is placed in the closest of the 480 sky brightness chart cells.)



Location Dialog

This dialog, accessed by pressing the **Location** button on the ***PPFD Information*** window, is the same as that accessed via the ***Information*** window.

Date and Time Dialog

This dialog, accessed by pressing the "date" button (the one with a date on it) on the ***PPFD Information*** window, is the same as that accessed via the ***Information*** window.

Canopy Photograph

This option, accessed by pressing the **Canopy Photograph** button on the ***PPFD Information*** window has the same effect as using the ***Below Canopy Photograph*** menu option, described below.

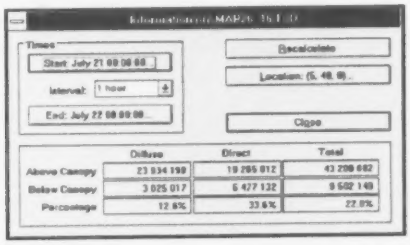
Below Canopy Photograph

A below canopy photograph represents a view of the canopy coverage, regardless of the time of day or year. The foliage amounts displayed are for full leaf out. This is discussed in more detail in the section on Page 80.

Longterm PPFD Calculations

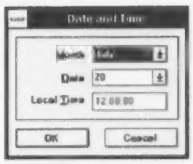
Instantaneous calculations are not always sufficient, so the user has the ability to perform long-term calculations which also take into account parameters such as tree species types, leaf in and drop periods, etc. The user can specify the start and end times for the calculation, as well as the accuracy. If the user requests a calculation to cross a yearly boundary, he will be warned, since this type of calculation isn't typical.

The beam components of total PPFD are placed and accumulated in the closest of the 480 sky brightness chart cells, described later (for instantaneous calculations, the beam component is calculated from the exact sun location over the plot).



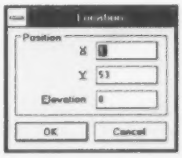
Date and Time Dialog

This option, accessed by pressing the **Start** and **End** buttons on the ***Longterm PPFD Calculations*** window, allows the user to specify the start and stop time used to calculate long-term PPFD values. Time must be entered in standard Windows™ time format (hours:minutes:seconds).



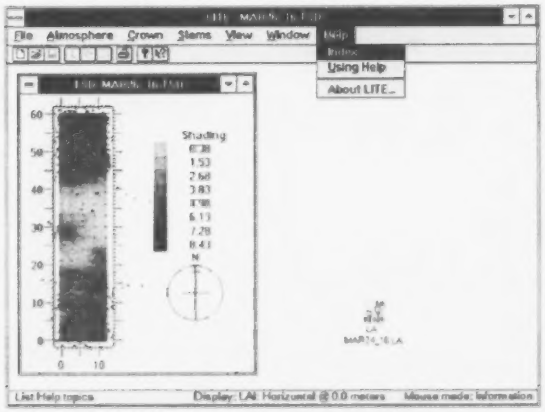
Location Dialog

From this dialog, accessed by pressing the **Location** button on the ***Information*** window, information can be entered to pinpoint a specific map location. The user is prompted to enter the **X** and **Y** coordinates (where 0,0 is in the lower, left-hand corner of the map), along with an **elevation**. Any numbers entered which are out of range will be modified to fit the range of valid data.



5.2.7 Help Menu

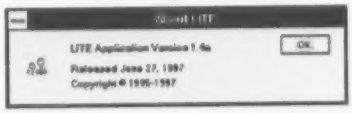
This menu displays program information and supports the user with on-line help. **Index** brings up a list of topics pertaining to LITE. **Using Help** brings up information on how to use the Help menu system. **About LITE** brings up the about-box for the program.



Index
Displays the Contents page for the LAI 2000/Tree Stand Modelling **Help**. The user can choose one of the topics by clicking on it with a pointing device or by selecting it with the **Tab** key and then pressing **Enter**.

Using Help
This is a standard feature in the Windows™ environment. It explains how to use **Help**.

About LITE
Displays information about the program, including the version number, copyright and license.

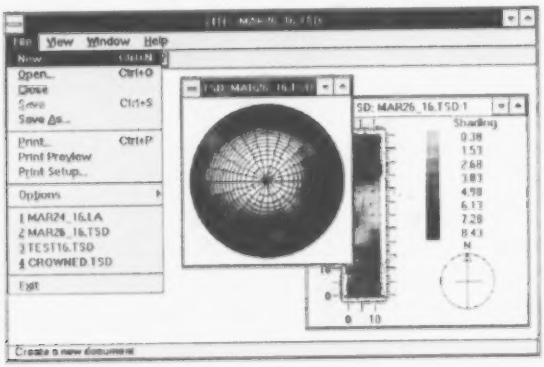


5.3 Below Canopy Photographs

A below canopy photograph presents another method of viewing the data in the TSD file. It represents the canopy found above a specified point in the map at full leaf-out. As long as the canopy photograph remains the active window, the menu items will be different because it is a different representation of a TSD file. While the ***Window*** and ***Help*** menus remain the same, there are no ***Atmosphere***, ***Crown*** or ***Stems*** windows, and the ***File*** and ***View*** menus are different as described below.

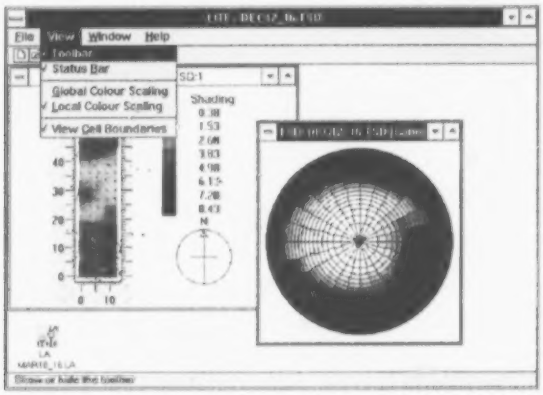
5.3.1 File Menu

The file operations remain the same, but are restricted to a subset of the generic TSD display because it is another representation of a TSD file. For example, one cannot export a below canopy photograph to a file.



5.3.2 View Menu

The view menu allows the user to determine how the canopy photograph will appear.



Toolbar

Selecting this item from the menu will toggle the toolbar on the main window. The toolbar, a group of buttons located directly under the main menu, can be used for quick access to commonly used commands if the user has a pointing device such as a mouse or Glidepoint™.

Status Bar

Selecting this item from the menu will toggle the status bar. The status bar, located at the bottom of the main window, provides information about the active document or highlighted command and also shows the state of the **CapsLock**, **NumLock** and **ScrollLock** keys.

Global/Local Colour Scaling

Users can select between global and local colour scaling. Selecting one will de-select the other (with global colour scaling being the default). Global colour scaling uses shades ranging from white (representing no canopy) to black (thickest canopy). With local colour Scaling, the range is from white (thinnest canopy) to black (thickest).

View Cell Boundaries

The user has the option to turn off the cell boundaries (grid-lines) of the canopy photograph. By default, they are turned on, and the associated menu item will have a checkmark beside it.

5.4 Calculations and Algorithms

5.4.1 Radiation

Above Canopy Radiation

The amount of radiation reaching a point directly above the canopy is a function of:

1. the position of the sun in the sky (solar time);
2. the amount of extraterrestrial radiation; and,
3. atmospheric conditions (pollution, clouds, etc).

Solar Time

Solar time is the time of day based on the position of the sun. Solar noon occurs when the sun is at its apex in the sky, and is different from local time. The solar time of the plot is calculated from local time, the timezone of the plot, and the longitude of the plot. Local standard time is corrected to determine Greenwich Mean Time (GMT) using the timezone. GMT is the solar time at longitude 0. Solar time at the plot is then calculated based on the longitude, which is the number of degrees of separation between 0 and the plot.

Extraterrestrial Radiation and Atmospheric Conditions

The formulas and constants in this section are drawn from *Spitters et al.* (1986). Total extraterrestrial radiation is set to 1370 J/(m^2s) and converted to 2596.15 μmoles/(m^2s) of PPFD by multiplying with a conversion factor of 2.04 (Meeh et al., 1984). Atmospheric conditions are based upon readings of instantaneous PPFD values (in μmoles/m^2s) recorded at one (1) hour intervals at a weather station.

The ratio of these measured PPFD values to the maximum expected PPFD is calculated for a given point in time. Maximum values are determined using formula (1) from *Spitters et al.* (1986) and the solar time. This calculated atmospheric transmission value is then used as the ratio of global PPFD above canopy to extraterrestrial PPFD (S_g/S_o) in formulas (20a-d). The result is a fraction diffuse value for radiation.

Ratio of Measured PPFD Above Canopy to Extraterrestrial PPFD (S_g/S_o)	Diffuse fraction of Total PPFD (S_d/S_g)
$S_g/S_o < 0.07$	$S_d/S_g = 1$
$0.07 <= S_g/S_o < 0.35$	$S_d/S_g = 1 - 2.3(S_g/S_o - 0.07)$
$0.35 <= S_g/S_o < 0.75$	$S_d/S_g = 1.33 - 1.46\ S_g/S_o$
$0.75 <= S_g/S_o$	$S_d/S_g = 0.23$

where:

S_d = diffuse irradiation above canopy

S_g = global (total) irradiation above canopy

S_o = extraterrestrial irradiation (a function of solar altitude and date)

The fraction, S_d/S_g, is used to separate the measured PPFD values into direct and diffuse above canopy values.

Direct Beam Radiation

The amount of direct radiation reaching a point in or under the canopy is a function of:

1. above canopy direct radiation;
2. direct beam path; and,
3. canopy conditions such as tree leaf area and tree species.

Direct Beam Path

The sun's position is used to determine the path of the direct radiation through the canopy of the stand. The cubes affecting the direct radiation can be determined along with the path length of the radiation through each cube.

The position of the sun is characterized by two angles from the reference point in the stand. The azimuth of the sun, α, is its compass direction in degrees and the elevation of the sun, β, is the number of degrees above the horizon. Note that β is not the same measure as used in the LAI 2000 device, which uses the number of degrees from the zenith.

The sun's azimuth, α, and elevation, β, at time of day t_h are calculated by:

$$\alpha = \sin^{-1}\left[\frac{\cos\lambda \sin\left[15(t_h - 12)\right]}{\cos\beta}\right]$$

and

$$\beta = \sin^{-1}\left[\sin\lambda\sin\delta + \cos\lambda\cos\delta\cos\left[15(t_h - 12)\right]\right]$$

where λ = latitude in degrees of the site

δ = solar declination in degrees calculated by

$$\sin\delta = -\sin(23.45)\cos\left[\frac{360(t_d + 10)}{365}\right]$$

t_d = number of days since January 1st

Canopy Conditions

Once the amount of direct radiation reaching the top of the canopy, Pb_o, and the path through the cubes forming the canopy has been determined, the amount of direct radiation reaching a point z under the canopy, Pb_z can be determined using Beers law (Norman and Welles, 1983):

$$Pb_z = Pb_o e^{\sum_i -G_i l_i d_i}$$

where

G_i is the light projection coefficient for the species in cube i
For broadleaf species, G_i is a constant that can be altered by the user (see, Leaf Coefficients page 55).

For Douglas-fir, G_i is determined with a function derived from *Black et al.* (1991) and cannot be altered by the user.

l_i is the leaf area in cube i (m^2 / m^3)

d_i is the path length through cube i

Diffuse Radiation

The amount of diffuse radiation reaching a point in or under the canopy is a function of:

1. above canopy diffuse radiation; and,
2. canopy conditions such as tree leaf area and tree species.

Canopy Conditions

Once the amount of above canopy diffuse radiation, Pb_o, has been determined, the amount of diffuse radiation reaching a point z under the canopy, Pb_z can be determined in a manner similar to the direct radiation. Rather than measuring the extinction of radiation along the path of a single ray, the total diffuse radiation is distributed evenly among 480 sample rays, assuming isotropic distribution of diffuse light, in the hemisphere. The total diffuse radiation is estimated by summing the radiation of these 480 rays.

The sample rays are the centres of equal areas of the hemisphere. The hemisphere is divided into 20 divisions from zenith to horizon (altitude) and 24 divisions of azimuth. The centre of the area is defined as the midpoint of the altitude angles and azimuth angles subtending the region.

Within the program, there is a user-specified horizon. It is assumed that any radiation below this horizon would be blocked by stems, branches, and geographic features. By default, approximately the bottom 10 degrees are occluded.

Each sample ray used is tracked through the canopy to determine which cubes it intersects and for what length. The species information of each cube is used to extinguish the sample ray. The calculation for each ray is the same as for the direct beam calculation detailed in the prior section.

5.4.2 Calculation of Exported Values

The calculation for all periodic values, either being sky brightness charts, above canopy readings, or below canopy readings are all performed at the same time. The calculations are performed in this manner because of the iterative nature of the calculations and the dependencies among them. The following section describes what kind of data can be exported. The second section outlines, in general, design decisions relating to the calculation of these values.

Definitions

Sky Brightness Chart

A sky brightness chart is a representation of the total sky intensity incident on a horizontal surface over a time period specified by the user. The sky brightness chart is divided into 480 equal-area divisions of the sky hemisphere (*Canham et al. 1994*). LITE's representation of a sky brightness chart keeps the diffuse and beam portions separate to correctly calculate the % transmittance. An example of a calculated sky brightness chart output can be found in **Appendix D - Sky Brightness Chart**, page 94.

As shown in the example, the sky is divided into 24 regions horizontally and 20 regions vertically to provide a total of 480 regions. Borders between regions are not spaced equally to ensure that all regions have the same area. The degrees mark the centre of the regions in the given plane.

For the calculation of a sky brightness chart, the user must specify:

- the azimuth of the plot, which is specified in the map file used to create the TSD file, and not modifiable by the user;
- global location, time zone of the plot, which is normally specified when the TSD file was created, but may be modified at any time;
- start and end times for the calculation, specifying the period that the sky brightness chart will represent; and,
- the calculation interval, used to specify how often the position of the sun is to be calculated.

The output of a sky brightness chart specifies details such as start and end times, calculation intervals, and location of the plot for future reference. The output also provides the total accumulated beam and diffuse PPFD for the specified time period. The table illustrates the locations of the beam components of the PPFD. For calculations, total diffuse PPFD is divided equally among the 480 regions. This value is also provided.

Above Canopy Readings

Above canopy readings are calculated from the same information used to calculate sky brightness charts. These readings represent total PPFD reaching the point just above the canopy, so attenuation through the atmosphere has been accounted for. An example of the output of above canopy readings can be found in **Appendix E - Above Canopy Readings**, page 95.

To calculate above canopy readings, the user must specify the same values for the calculation of the sky brightness chart, as well as:

- the output interval, which specifies the period of time between outputs to the file. The output interval is always a multiple of the calculation interval, to simplify internal logic. Separating the calculation interval from the output interval allows the user to specify greater accuracy without the same volume of output (e.g., calculation interval of 15 minutes but output data once per day).

The output of this file directly corresponds to the matching sky brightness chart. The sum of all beam and diffuse PPFD (given for each output time interval) will match the total beam and diffuse components in the corresponding sky brightness chart.

Each entry represents accumulated diffuse, direct, and total PPFD, and the average sun location for the time period and interval specified. The date and time represent the mid-point of a time period. For example, the entry for Jan 1 for the time period from 08:15:00 to 08:30:00 is 08:22:30, since the output interval is 15 minutes.

Below Canopy Readings

Below canopy readings represent the amount of PPFD which penetrates the canopy at a point specified by the user. This point does not necessarily have to be at the canopy floor. An example of the output can be found in **Appendix F - Below Canopy Readings**, page 96.

To calculate below canopy readings, the user must specify the same values for the calculation of above canopy readings, plus:

- the location within the plot specifying the point for which below canopy readings are to be calculated. This may actually be above the canopy, which results in below canopy readings being relatively equal to above canopy readings; and,
- stems (which must each be associated with a species type), and a default stem species type for the plot. This species information is normally taken from application defaults upon creation of the TSD file, and may be modified by the user. This information is used to determine leaf in and leaf drop times, and to determine the light projection coefficient for the species. Again, all these values may be changed by the user. Stems may be attached in bulk, and individually entered, modified, and removed in other portions of LITE.

Output values correspond to values in above canopy output. The final column represents the GLI for the period, or percentage of the PPFD traveling through the canopy.

Calculation of Periodic Values

Before any calculation takes place, start and end dates are checked. If the period specified by the user crosses a year boundary, the user is warned and asked whether to continue.

Start and end times are given in local time, but are converted to solar time when calculating sun positions. However, when calculating output PPFD for a period of time, local time is used since sky condition PPFD values are loaded and stored in local times. Finally, all output is given in local time to avoid confusion among the times specified by the user and times given in the output.

For each calculation interval, the local time and plot location are used to calculate a solar time which is converted into a sun location (elevation and azimuth). The total above canopy PPFD is determined either by interpolation of input values from the .pfd file (see **Open Sky PPFD File (*.pfd)** on Page 42) or calculated by using the sun's elevation and atmospheric conditions previously set by the user. The sun location is then used to:

- separate the total PPFD for the calculation interval into diffuse and direct PPFD; and,
- to identify the location of the beam in the sky brightness chart.

For long-term calculations, the beam component of the total PPFD is placed in the closest of the 480 sky brightness chart cells, and accumulated over the entire time specified by the user. These accumulated values are shown in the example sky brightness chart output, above.

The algorithms used to calculate below canopy readings take into consideration leaf in and leaf drop times. For each week during the period between leaf in and leaf drop, the average amount of leaf area is calculated and used when determining the amount of canopy to use as a filter for above canopy PPFD. Leaf in and drop dates are specified for each species, and can be inspected and modified by the user.

The "below canopy readings example" shows that the percentage is very high, but never 100%. The reason for this is because there is no leaf area (after leaf drop, before leaf in) for the species in January. The value never reaches 100% because the bottom three rings (72 of the 480 regions) of the sky brightness charts are always excluded from the calculation of below canopy readings. However, they are present in above canopy sky readings and in the sky brightness chart. The reasoning for this is because these rays extend out at extremely low angles from horizontal, thus making these values rather inconsequential, due to the amount of atmosphere and canopy through which these rays must travel. Currently, the user may not modify this design decision.

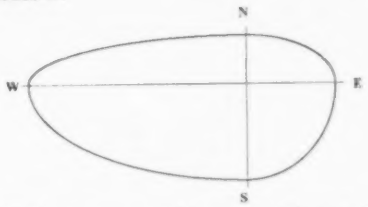
If the calculation interval is less than the output interval, all calculated values are accumulated until the next output interval occurs. All values for a calculation interval are calculated from the mid-point of the interval as an instantaneous value and multiplied by the number of seconds in that interval. For example, if the interval is 15 minutes, at 8:00am, the sun position and PPFD will be calculated for 8:07:30am. Thus, changing the calculation interval affects both the accuracy of the calculation and the time required to perform the calculation.

If the start and end times for the calculations do not specify an integral number of intervals, for example the interval is 15 minutes, but the time period between start and end times is 55 minutes, then the final calculation interval is adjusted to correct this. The start and end times are not adjusted to match intervals. So, in this example, the last interval will be 10 minutes in length, starting at 45 minutes, ending at 55 minutes, and the sun location will be calculated at 50 minutes.

5.4.3 Crown Generation

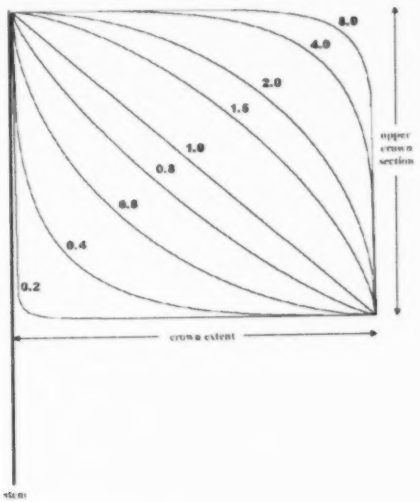
Crowns are generated for all stems attached to a plot, even if the stem is outside of the plot boundaries. This ensures areas in the plot which are associated with stems that reside outside of the plot still receive appropriate LA values.

The crowns are defined by four quarter-ellipses. Each ellipse shares major and minor axes with its two neighbours. The major and minor axes are defined by the crown extent measurements for each of the four cardinal directions, as shown below:



The crown is divided into upper and lower sections using the ratio of the crown belonging to the upper half. The vertical crown curvature for both these sections is defined by the power-factor for the upper and lower sections of the crown. This information is provided by the user through the *Tree Morphology Coefficients* dialog box, and is constant for all four quarter-sections.

The diagram below shows several sample vertical crown curvatures for an upper crown section. A power factor of 1.0 corresponds to a straight line. A factor of 2.0 results in an ellipse. If the factor is greater than 2.0, the crown curve will become more convex and eventually rectangular as the factor approaches infinity. Conversely, a factor of less than 1.0 will produce a concave crown curve (Koop 1989).



Voxels, or volume-elements (in this case one-metre cubes), that lie within the boundaries of the formulas which define the crown are marked and added to a list of voxels owned by the stem.

The total LA to be associated with the stem/tree is calculated from the following equation:

LA = 2.0 * foliage_biomass * 1000 *s_LA / 100 / 100 * sin(leaf_angle)

where:

2.0=Leaves are double-sided.
* foliage_biomass(species_index, diam, height)=
Foliage biomass is calculated as a function of the stem's species type, its diameter, and its height. The height may be calculated from the diameter.
* 1000=Converting from grams to kilograms.
* s_LA=Specific leaf area (constant for a species).
/100 /100=Converting from cm^2 to m^2
* sin(leaf_angle)=Leaf angle (constant for a species).

Once the total LA to be associated with a stem has been calculated, it is divided by the total number of voxels associated with the crown space, whether they exist or not (to ensure the proper density for each voxel). The calculated density is assigned to each voxel which exists for the tree and the voxel is associated with that stem.

Each voxel can only be associated with one stem. If a voxel lies within the crown-space of more than one stem, it will remain associated with the last stem (where stems are processed in numerical order)

Appendix A - Open Sky PPFD File (*.pfd)

[Day]	[Time]	[PPFD]
147	0	0
147	100	0
147	200	0
147	300	0
147	400	0
147	500	29.2
147	600	182.9
147	700	451.9
147	800	767
147	900	1075
147	1000	1330
147	1100	1558
147	1200	1659
147	1300	1668
147	1400	1563
147	1500	1046
147	1600	660.7
147	1700	653.1
147	1800	359.6
147	1900	161.2
147	2000	31.06
147	2100	0
147	2200	0
147	2300	0

Stem list: version 4
Elements: 636
Format:

Stem_ID	Species	x	y	diam.	lean_%	lean_dir.	[height	[htcb{n, e, s, w}				[radius{n, e, s, w}				[total_LA]]]]
74	DR	13.05	6.11	4.05	0.00	0.00	7.5	3.37	0.00	3.32	3.13	1.28	1.49	1.29	1.31	4.90
75	DR	10.45	7.21	3.69	0.00	0.00	7.2	3.18	3.44	2.90	3.54	1.21	1.17	1.24	1.16	21.10
76	DR	10.94	9.54	9.00	0.00	0.00	10.7	4.49	4.82	4.06	4.88	1.93	1.84	1.99	1.82	4.54
77	DR	10.50	9.88	3.32	0.00	0.00	6.7	3.24	3.78	3.10	3.54	1.09	0.96	1.11	1.04	5.89
78	DR	11.47	9.08	2.55	0.00	0.00	5.7	2.96	3.43	3.32	3.42	0.86	0.76	0.79	0.76	5.59
79	DR	12.29	9.29	4.46	0.00	0.00	7.9	3.61	3.74	4.17	3.98	1.34	1.32	1.18	1.26	5.43
80	DR	12.14	8.89	3.47	0.00	0.00	6.9	3.89	3.43	3.81	3.77	0.97	1.11	1.01	1.02	4.35
81	DR	11.67	8.19	2.78	0.00	0.00	6.0	3.45	3.65	2.70	3.13	0.86	0.77	0.98	0.93	4.92
82	DR	12.07	8.29	1.98	0.00	0.00										
83	DR	12.25	8.09	2.59	0.00	0.00	5.8	3.64	3.64	2.79	3.49	0.66	0.66	0.91	0.75	3.83
84	DR	12.50	7.98	3.75	0.00	0.00	7.2	3.72	3.64	3.28	4.04	1.13	1.15	1.21	0.98	4.53
85	DR	13.60	8.36	8.24	0.00	0.00										
86	DR	13.56	8.67	4.73	0.00	0.00										
87	DR	13.59	8.85	4.07	0.00	0.00										
188	DR	21.62	14.35	1.89	0.00	0.00										
246	DR	17.93	14.43	7.12	0.00	0.00										
248	DR	16.44	13.91	2.66	0.00	0.00										
262	DR	13.73	9.94	1.46	0.00	0.00										
265	DR	13.31	10.82	2.46	0.00	0.00										
266	DR	9.79	11.48	1.62	0.00	0.00	3.9	1.96	2.41	2.48	2.85	0.53	0.48	0.47	0.39	8.87
267	DR	11.91	15.10	12.20	0.00	0.00	11.9	4.93	3.35	4.85	4.08	2.17	2.33	2.18	2.28	14.36
268	DR	11.10	15.97	8.22	0.00	0.00	10.3	3.83	2.44	4.49	3.77	1.92	2.01	1.83	1.93	33.47
269	DR	11.14	13.97	8.27	0.00	0.00	10.4	4.42	4.39	4.18	4.06	1.85	1.86	1.89	1.90	11.67
270	DR	12.52	13.53	6.43	0.00	0.00	9.4	4.00	3.84	4.12	4.11	1.66	1.68	1.64	1.64	11.63
271	DR	12.02	12.20	2.95	0.00	0.00	6.3	3.26	3.00	3.50	3.67	0.97	1.01	0.92	0.85	6.55
272	DR	11.50	12.11	5.38	0.00	0.00	8.7	3.71	4.33	4.14	3.74	1.52	1.37	1.43	1.51	5.65
273	DR	12.79	11.37	1.38	0.00	0.00										
274	DR	12.27	11.09	2.11	0.00	0.00										
275	DR	12.02	11.19	1.33	0.00	0.00	3.1	2.96	2.90	2.15	2.76	0.00	0.09	0.32	0.18	4.89
277	DR	14.01	12.13	11.00	0.00	0.00										
280	DR	11.94	11.30	1.92	0.00	0.00										
281	DR	11.60	10.79	4.57	0.00	0.00	8.0	4.11	4.12	3.74	3.74	1.25	1.24	1.34	1.35	4.47
282	DR	9.44	9.66	4.97	0.00	0.00	8.3	3.64	3.99	3.83	4.03	1.45	1.38	1.42	1.37	6.04
283	DR	8.64	10.26	7.32	0.00	0.00	9.9	4.45	4.45	4.55	4.72	1.71	1.71	1.68	1.60	5.69
284	DR	8.14	9.65	3.86	0.00	0.00	7.3	3.89	3.61	3.45	3.80	1.11	1.19	1.22	1.14	10.91

[...remaining entries omitted]

Appendix C - Observation Point Map File (*.map)

```
; Azimuthal of (0,0),(0,1)
305
; Number of tags
40
;tag,x,y,htcb,httc
221, 8, 5, 6.1, 11.5
222, 8, 15, 6.1, 11.5
223, 8, 25, 6.1, 11.5
224, 8, 35, 6.1, 11.5
225, 8, 45, 6.1, 11.5
226, 8, 55, 6.1, 11.5
227, 8, 65, 6.1, 11.5
228, 8, 75, 6.1, 11.5
229, 24, 5, 6.1, 11.5
230, 24, 15, 6.1, 11.5
231, 24, 25, 6.1, 11.5
232, 24, 35, 6.1, 11.5
233, 24, 45, 6.1, 11.5
234, 24, 55, 6.1, 11.5
235, 24, 65, 6.1, 11.5
236, 24, 75, 6.1, 11.5
237, 40, 5, 6.1, 11.5
238, 40, 15, 6.1, 11.5
239, 40, 25, 6.1, 11.5
240, 40, 35, 6.1, 11.5
241, 40, 45, 6.1, 11.5
242, 40, 55, 6.1, 11.5
243, 40, 65, 6.1, 11.5
244, 40, 75, 6.1, 11.5
245, 56, 5, 6.1, 11.5
246, 56, 15, 6.1, 11.5
247, 56, 25, 6.1, 11.5
248, 56, 35, 6.1, 11.5
249, 56, 45, 6.1, 11.5
250, 56, 55, 6.1, 11.5
251, 56, 65, 6.1, 11.5
252, 56, 75, 6.1, 11.5
253, 72, 5, 6.1, 11.5
254, 72, 15, 6.1, 11.5
255, 72, 25, 6.1, 11.5
256, 72, 35, 6.1, 11.5
257, 72, 45, 6.1, 11.5
258, 72, 55, 6.1, 11.5
259, 72, 65, 6.1, 11.5
260, 72, 75, 6.1, 11.5
```

Appendix D - Sky Brightness Chart

Sky Brightness Chart in PFD

Start time (local): Jan 1 04:00:00
End time (local): Jan 2 04:00:00
Interval for calculations: 00:15:00
Location of plot:
Latitude: 49.0 North
Longitude: 123.0 West
Azimuth of plot (geographic): 360.0
Total Beam for time period: 14862214.0
Total Diffuse for time period: 18446818.0
Total Diffuse per Cell for time period: 38426.6

Beam Component by S.B.C. Cell:

elevation 1.4	4.3	7.2	10.1	13.0	16.0	19.0	22.0	25.2	28.4	31.7	35.1	38.7	42.5	46.5	50.8	55.6	61.0	67
azimuth																		
82.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
67.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
52.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
37.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
22.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
7.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
352.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
337.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
322.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
307.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
292.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
277.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
262.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
247.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
232.5	368794	271890	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
217.5	0.0	0.0	723033	960475	567006	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
202.5	0.0	0.0	0.0	0.0	622830	2052392	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
187.5	0.0	0.0	0.0	0.0	0.0	1437187	1386300	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
172.5	0.0	0.0	0.0	0.0	0.0	576635	1903590	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
157.5	0.0	0.0	0.0	0.0	434924	1525863	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
142.5	0.0	0.0	506696	670756	395822	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
127.5	113629	344295	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
112.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
97.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1

Appendix E - Above Canopy Readings

```
Start time (local):     Jan  1 04:00:00
End time (local):       Jan  2 04:00:00
Calculation Interval:   00:15:00
Output Interval:        00:15:00

Location of plot:
        Latitude:   49.0 North
       Longitude:  123.0 West

Format:
Date   Time     (sun_horiz (geographic)  sun_vert  total_PFD  PFPD_beam  PFPD_diffuse]
(calculation is centered around interval_len)
Jan  1 04:07:30
[ ... empty entries omitted for brevity...]
Jan  1 08:07:30                              1.7     569531.3   113629.8   455901.5
Jan  1 08:22:30  129.0                       1.7     569531.3   113629.8   455901.5
Jan  1 08:37:30  132.0                       3.6     611718.8   152208.1   459510.7
Jan  1 08:52:30  135.0                       5.3     653906.3   192087.7   461818.6
Jan  1 09:07:30  138.0                       7.0     696093.8   232796.3   463297.5
Jan  1 09:22:30  141.0                       8.6     738281.3   273900.2   464381.1
Jan  1 09:37:30  144.0                      10.1     780468.8   315004.4   465464.3
Jan  1 09:52:30  147.0                      11.5     822656.3   355752.2   466904.1
Jan  1 10:07:30  150.0                      12.8     864843.8   395822.0   469021.7
Jan  1 10:22:30  154.0                      13.9     907031.3   434924.0   472107.3
Jan  1 10:37:30  157.0                      14.9     949218.8   472794.5   476424.2
Jan  1 10:52:30  161.0                      15.8     991406.3   509189.8   482216.4
Jan  1 11:07:30  164.0                      16.5    1033593.8   543878.9   489714.9
Jan  1 11:22:30  168.0                      17.1    1075781.3   576635.3   499145.9
Jan  1 11:37:30  171.0                      17.5    1117968.8   607229.4   510739.4
Jan  1 11:52:30  175.0                      17.8    1160156.3   635419.0   524737.3
Jan  1 12:07:30  178.0                      17.9    1202343.8   660942.3   541401.5
Jan  1 12:22:30  182.0                      17.9    1244531.3   683508.5   561022.8
Jan  1 12:37:30  186.0                      17.7    1286718.8   702791.9   583926.9
Jan  1 12:52:30  189.0                      17.3    1328906.3   718424.8   610481.5
Jan  1 13:07:30  193.0                      16.9    1350000.0   718762.2   631237.8
Jan  1 13:22:30  196.0                      16.2    1350000.0   704029.8   645970.3
Jan  1 13:37:30  200.0                      15.4    1350000.0   685469.9   664530.1
Jan  1 13:52:30  203.0                      14.5    1350000.0   662892.2   687107.8
Jan  1 14:07:30  207.0                      13.4    1321875.0   622830.3   699044.7
Jan  1 14:22:30  210.0                      12.3    1265625.0   567006.6   698618.4
  [...remaining entries are omitted]
```

```
Start (solar time):     Jan  1 04:00:00
End (solar time):       Jan  2 04:00:00
Calculation Interval:   00:15:00
Output Interval:        00:15:00

Location of plot:
          Latitude:     49.0 North
          Longitude:    123.0 West

Location within plot:
  (0.0, 0.0, 0.0)
Format:
Date   Time      [sun_horiz (geographic)  sun_vert  total_PFD  PPFD_beam  PPFD_diffuse
total_percent]
(calculation is centered around interval_len)
Jan  1 04:07:30
[ … empty entries omitted for brevity…]
Jan  1 08:07:30
Jan  1 08:22:30  129.0                    1.7       387514.9   0.0        387514.9      68.0
Jan  1 08:37:30  132.0                    3.6       390583.6   0.0        390583.6      63.9
Jan  1 08:52:30  135.0                    5.3       392546.8   0.0        392546.8      60.0
Jan  1 09:07:30  138.0                    7.0       393800.8   0.0        393800.8      56.6
Jan  1 09:22:30  141.0                    8.6       394724.1   0.0        394724.1      53.5
Jan  1 09:37:30  144.0                    10.1      710649.6   315004.4   395645.2      91.1
Jan  1 09:52:30  147.0                    11.5      752621.4   355752.2   396869.2      91.5
Jan  1 10:07:30  150.0                    12.8      794489.3   395822.0   398667.3      91.9
Jan  1 10:22:30  154.0                    13.9      836216.7   434924.0   401292.7      92.2
Jan  1 10:37:30  157.0                    14.9      877756.2   472794.5   404961.6      92.5
Jan  1 10:52:30  161.0                    15.8      919075.8   509189.8   409886.0      92.7
Jan  1 11:07:30  164.0                    16.5      960137.7   543878.9   416258.8      92.9
Jan  1 11:22:30  168.0                    17.1      1000908.0  576635.3   424272.7      93.0
Jan  1 11:37:30  171.0                    17.5      1041357.1  607229.4   434127.7      93.1
Jan  1 11:52:30  175.0                    17.8      1081443.2  635419.0   446024.2      93.2
Jan  1 12:07:30  178.0                    17.9      1121131.5  660942.3   460189.2      93.2
Jan  1 12:22:30  182.0                    17.9      1160380.5  683508.5   476872.0      93.2
Jan  1 12:37:30  186.0                    17.7      1199127.2  702791.9   496335.3      93.2
Jan  1 12:52:30  189.0                    17.3      1237336.2  718424.8   518911.4      93.1
Jan  1 13:07:30  193.0                    16.9      1255317.1  718762.2   536554.9      93.0
 […remaining entries omitted]
```

FILE	DATE	TIME	PLOT	POINT	LAIapt	SEL	DIFN	MTA	SEM	SMP
85	10 JUL	08:19:47	H270B	25	2.19	0.00	0.211	60	9	1

ANGLES	7.000	23.00	38.00	53.00	68.00
CNTCT#	1.209	0.638	1.113	1.544	0.993
STDDEV	0.000	0.000	0.000	0.000	0.000
DISTS	1.008	1.087	1.270	1.662	2.670
GAPS	0.296	0.500	0.243	0.077	0.071

A	42	08:20:55	10.92	9.330	9.757	12.06	13.75
B	1	08:20:42	3.227	4.665	2.374	0.926	0.971

FILE	DATE	TIME	PLOT	POINT	LAIapt	SEL	DIFN	MTA	SEM	SMP
86	10 JUL	08:20:51	H270B	25	1.64	0.00	0.289	59	9	1

ANGLES	7.000	23.00	38.00	53.00	68.00
CNTCT#	0.928	0.537	0.849	1.144	0.726
STDDEV	0.000	0.000	0.000	0.000	0.000
DISTS	1.008	1.087	1.270	1.662	2.670
GAPS	0.392	0.558	0.340	0.149	0.144

A	42	08:20:55	10.92	9.330	9.757	12.06	13.75
B	1	08:20:56	4.286	5.206	3.320	1.802	1.977

FILE	DATE	TIME	PLOT	POINT	LAIapt	SEL	DIFN	MTA	SEM	SMP
87	10 JUL	08:21:02	H270B	24	0.35	0.00	0.796	90	0	1

ANGLES	7.000	23.00	38.00	53.00	68.00
CNTCT#	0.037	0.026	0.031	0.175	0.259
STDDEV	0.000	0.000	0.000	0.000	0.000
DISTS	1.008	1.087	1.270	1.662	2.670
GAPS	0.963	0.972	0.961	0.748	0.501

A	43	08:21:25	10.93	9.337	9.760	12.06	13.75
B	1	08:21:23	10.53	9.076	9.384	9.016	6.894

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